UNIVERSITY OF SAINT JOSEPH
聖若瑟大學

MUSIC TRAINING INFLUENCES ON BRAIN DEVELOPMENT AND AS A TOOL FOR LEARNING IMPROVEMENT

A Thesis
Presented to
The Academic Faculty

by

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DEDICATED

To my grandmother Ana,
Who I have never met,
a role model that has been a source of inspiration
and perseverance in my life.

To Ah Mah,
My beloved dog, living now in rainbow,
a faithful companion that will be in my heart forever

I certify that this report is solely my work, and that it has never been previously submitted for any academic award.

Ana Filipa Neves Ferreira

I, the supervisor, believe that this Thesis is ready for assessment, and reaches the accepted standard for the Master of Education.

Ana Maria Correia

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ABSTRACT

The final purpose of this thesis is to explain and justify how early music training can be considered an additional educational tool to prepare the brain for a better learning improvement and human aesthetic-scientific balanced development. For that purpose the study conducts a qualitative research approach based on the most relevant literature review about neuroscience, music and education and applies an integrative, interdisciplinary and critical reflection to present and to justify the multiples benefits of early music training instruction.

The notable advances on neuroscience findings related to music and/or education were taken in special consideration, such as those concerned with the concepts of neuroplasticity, sensible periods, nature and nurture on brain development, transfer of learning, musical abilities and nonmusical abilities.

The scope of the dissertation is concentrated on music training. Music training is about learning and practicing a musical instrument, based on musical theories, notation, techniques, and cultural and emotional environments. Other delimitation on the scope of the study refers to the functional uses of music on therapy or clinical rehabilitation, which are not considered in this dissertation despite their relevant and confirmed social and medical benefits.

The singular life experience of the author, as pianist, musical educator and a master student on education, explains the affective and motivation by the nature of thematic proposed, which also allows her to be more insightful on exposing findings, ideas, opinions and reflections when doing the interdisciplinary, integrative and critical literature overview included on discussion and conclusions.

This dissertation might contribute to the dissemination of the neuroscience findings on music training and its implications for education and lifelong learning. Future research should build more bridges between music, neuroscience and education to strengthen the important field of educational neuroscience and the need to include musical education in the school curriculum.

Keywords: music training, neuroplasticity, musical abilities, nonmusical abilities, transfer, music education

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1. INTRODUCTION

1.1. BACKGROUND OF THE STUDY

This dissertation involves an interdisciplinary scientific area that during the last two decades has been object of a notable increasing research and vast academic literature, although mainly focused in the dual areas of the neuroscience and music and neuroscience and education, and not so much in the interconnection of the three academic fields - Music, Neuroscience and Education.

Education is about the processes and dynamics of learning and neuroscience is about understanding the brain processes involved in learning. According to the scientific advances on brain imaging techniques, neuroscience has been able of better understanding how the human brain learns and develops. By 2007, a publication of the OECD "Understanding the Brain: The Birth of a Learning Science", represented an historical milestone on the affirmation of the emergency of the neuroscience applied to education.

Music training is about learning and practicing a musical instrument, based on musical theories, notation, techniques, and cultural and emotional environments. Neuroscience applied to music had also registered a notable progress in the last decades. Music has been also considered the food of neuroscience (Zatorre, 2005) by its extraordinary capacity to allow researchers to observe the structural and functional brain changes in response to musical stimuli, related with acquisition and practice of musical abilities.

The brain's capacity to change its structure and function during learning or facing new environmental experience-dependent stimulus is today well known as neuroplasticity. Neuroplasticity constitutes one of the most remarkable features of the human brain and one of the most relevant scientific findings in neuroscience, with strong implications on educational theories and on design of new learning environments.

A large academic literature around music and its brain effects has been developed since the famous research article published in 1993 in Nature by Rauscher, Shaw and Ky, which received widespread attention and a popular designation as the "Mozart effect". After that research article, which refers to temporary spatial reasoning effects on music listening, a large amount of neuroscience literature has been developed focusing on music training and neuroplasticity, and correlated structural and functional brain's changes. Brains of musicians are different than those nonmusicians and music training has been considered a tool for promoting brain plasticity across the life span.

More recently, the factors underlying neuroplasticity induced by musical instrumental training and the transfer effects of musical skills to non-musical domains, such as literacy, numeracy, intellectual development, social and emotional skills, have been contributed to scientific progress with their findings suggesting that music training provides a greater plastic brain and that musicians have an increased potential of learning compared to nonmusicians.

Under this scientific overall background, this theme intends to advocate that music learning and practicing a musical instrument can improve, with more evidence since early ages, cognitive, emotional and social aspects of the human brain development and subsequently be a powerful tool to enhance learning during the schooling period and across the life span.

Trying to explain how music training, like piano practice, can improve brain development, namely with the fundamental capacity of the music to induce experience-dependent neuroplasticity and alter the capacity of the brain to adapt to the ever-changing learning environment, is the central aim of the study.

The Discussion chapter is reserved to highlight and integrate the most relevant findings on neuroscience, music and education, to advocate the introduction of music training during childhood as a powerful tool to improve learning and a balanced artistic-emotional-scientific human development.

1.2. FOCUS, MOTIVATION AND SIGNIFICANCE OF THE STUDY

The author as pianist, musical educator and a master student on education, and also with an educational background as piano student since early ages is guided by a singular and strong motivation that explains the affective reason of the thematic proposed. The singular life experience, musical background and professional qualification allows her to understand better the current theme, to be more insightful about exposing findings, ideas and reflections when does the interdisciplinary and integrative literature overview and then proceeds to the discussion and conclusions.

The motivation around this theme is also derived from the conference paper Music, Neuroscience and Education presented on December 2013 (by the author), which proportionated a first literature contact with the fascinating world of the science of the nervous system and their connections with the scientific fields of music and education.

The main focus of the research is to underline the relevance of the most updated and exponential scientific advances on the neuroscience applied to music and their subsequent findings regarding the merits of music training to improve the brain's neuroplasticity and transfer of multiple benefits to nonmusical domains. Music training might be recognized as a powerful educational tool to proportionate a children's better neural network capable of enhancing the learning and adapting to external environment through life span.

By this way the contribution of this research, although the theme is not entirely innovative, it may be relevant to education in the sense that provides an integrative overview of the virtuosi connection between music, neuroscience and learning of musical training education and their benefits to cognitive, social, emotional and human well-being development.

1.3. RESEARCH PROBLEM AND RESEARCH QUESTION

This qualitative study is built around the following general question:

What is the impact of music training in cognitive and personal development?

Undertaking research in this area of knowledge requires an interdisciplinary approach in which neuroscience and education are the main disciplines. Based on the scientific findings concerning the benefits of music training with regard to the cognitive and personal development, the study aims to shed light over the importance of the inclusion of music training in the school curriculum and is intended to answer to the research question stated below:

Why music training should be introduced in the school curriculum?

Listening to the voice of a pianist who is also the author of the present study allows the reader to have a first-hand evidence of the role played by music in cognitive and personal development of children and adolescents.

1.4. SCOPE AND LIMITATIONS

Two essential limitations to the scope of the study were introduced. First, the dissertation is focused on music training rather than on music listening or music background, which are forms of not active engagement with music.

Music training instruction has the main object to learn and practice a musical instrument, such as keyboard, strings, winds and percussion instruments. This area of music instruction is susceptible to integrate vocal or choral instruction, although the majority of the research on neuroscience of music has been focused preferentially on instrumental music and their neural plasticity and other effects on the brain. The concept of music training in the dissertation is also identified as music training, music education or formal music instruction. Music learning and practicing a musical instrument should be focused on individual lessons with a qualified teacher, as well as including instrumental music lessons in group, such as music chamber, orchestra and choral. A formal music training curriculum also includes the courses of sigh reading (how to read and translate notation into music), music theory, aural training, music history and culture history. Music training also implies to train the auditory system to a better sound discrimination and response to complex instrumental tones, including pitch ability, rhythm, scales, harmony, melody and other music relations. Music composition and/or music improvisation could be also integrated in the music curriculum, but perhaps in a later phase of the instrumental practice.

Most of the neuroimaging findings on the neuroscience of musical training were a result of the comparisons between brain's musicians and nonmusicians. In this dissertation it is important also to discriminate the professional musicians from the amateur musicians, as well as the age of commencement of music training, among other influent variables on neural plastic changes induced by music and possible learning transfer and benefits to nonmusical domains.

The other limitation on the scope of the study refers to the functional uses of music on therapy or clinical rehabilitation, which are not considered in this dissertation despite its relevant role in dyslexia, ageing neural degradation, autism and other neurological disorders. Listening or playing music and singing has been scientific proved to induce neuroplasticity and proportionate emotional and reward experiences in the rehabilitation of patients with brain disorders.

1.5. STRUCTURE OF THE PRESENTATION

The thesis is structured in 5 Chapters. Chapter 1 is an Introduction to the study, including the identification of the research line, its background, focus, significance, scope and methodological aspects.

The literature overview is presented in the Chapter 2, which is divided in three parts, namely an introduction to the science of the nervous system (2.1), an association between music training and their implications on brain changes (2.2) and a presentation of music training and their positive effects on nonmusical domains and as a tool for learning improvement (2.3).

The Chapter 3 refers the methodology, which used an autobiographical approach, followed by the discussion and conclusions. Overall, the integrative literature review on the music, neuroscience and education intends to be a critical reflection and argumentation centered on the introduction of music training on early phases of the educational process as a tool to improve lifelong learning and benefits to cognitive, emotional, social and other aspects of human development.

The Chapter 4 is dedicated to presentation and reflections of narratives of autobiography.

Finally, Chapter 5 exposes the discussion and points out conclusions in response to the research problem and research questions.

2. LITERATURE REVIEW

2.1. NEUROSCIENCE: THE SCIENCE OF THE NERVOUS SYSTEM

The development of the brain is affected by genetic, environmental and random factors, each of them influencing the uniqueness of individual human brain and mind. Over lifetime the human brain is sufficiently plastic to change or adopt their neural system to experience-dependent learning process, namely to learn a language or other cognitive practice.

Neuroscience is the science of the nervous system, or the science of the brain, since this organ is the central and most complex structure of the nervous system.

The deconstruction of the word “neuroscience” let us know in its origin the terms “neuron” and “science”. Neuron is the anatomical and functional unit of the nervous system, which consists of a nerve cell body, dendrites (which receive an electrical-chemical signal of the other neurons), and an axon (which transmits the electrical-chemical signal to another neuron).

Neuroscience involves the study of the brain and their interactions with the central and peripheral nervous system. It comprises the scientific research of its organization, functioning, and underlying neurophysiology. This one is dedicated to the study of the neurons and other nerve cells, neurotransmitters, synapses, and neural networks that integrate the nervous system.

The main focus of this dissertation will be on cognitive neuroscience of music and educational neuroscience, without excluding the importance of other correlated scientific research fields or, even better, an interdisciplinary view of the neuroscience, music and education. Specifically, we couldn’t sub evaluate the emotional brain interaction with music and the role of the emotions on the music processing and brain development effects.

The notable development of the neurosciences research findings in the last two decades is a partial result of the advance on the use of brain imaging technologies. Since the first use of brain scanning techniques in the 1970s, through the computerized axial tomography (CAT) and positron emission tomography (PET), a more recent and less invasive scanning technique – the functional magnetic resonance imaging (fMRI) – has been used by neuroscientists with more efficient results on research methods and conclusions. In particular, using the fMRI, scientists have been able to map some areas of the brain that were activated when a person performs a systematic specific task, like for instance while practicing a musical instrument.

The educational neuroscience or the neuroscience applied to education has emerged as a relevant topic in this century. A more intensive and qualified research on how the brain develops and learns has the potential to have a profound impact on education and on life long learning.

The nexus of the music and education lies on the neuroplasticity. Neuroplasticity is a fundamental concept in neuroscience. It refers to brain's capacity to change and adapt in response to developmental forces, learning processes, or ageing, or in response to an injury in a specific area of the brain.

Education changes the neural structures of the brain and contributes to the learning capacity over lifetime. Learning and practicing music, especially since the early years, enables the brain to be more active and flexible and to develop more competences and skills. It seems that the future tendencies point to a bridging interdisciplinary research field: neuroscience – music – education.

The present dissertation, supported on neuroscience literature and research evidence, may be interpreted as an interdisciplinary scientific contribution for a better comprehension how the music practice shapes the brain and could have positive influences on other cognitive areas and on learning through long life.

2.1.1. BRIEF PRESENTATION OF THE NERVOUS SYSTEM

According to Carter (2009) and other sources, the anatomy of human nervous system consists of two main components. One part, the central nervous system (CNS) includes the brain stem, cerebellum and spinal cord. The CNS receives and processes information on brain and integrates the activity of the rest of the body. The other component, the peripheral nervous system (PNS) is the part of the nervous system that includes all the nerves outside the brain and spinal cord. The PNS interacts with CNS and it is composed by 31 pairs of spinal nerves and by 12 cranial nerves. (see figure 1).

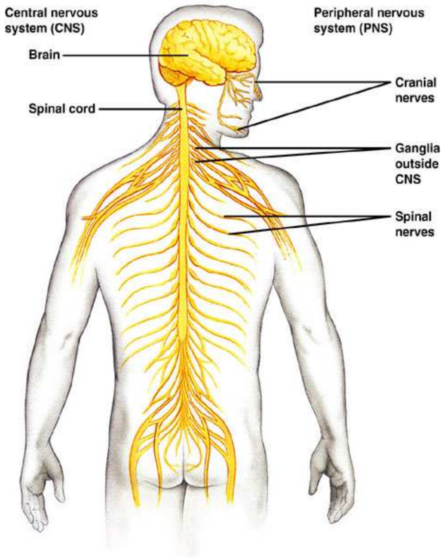

Figure 1. Nervous System

The nervous system is a complex and vital structure of the human body to process information like thinking, learning, memory and emotion, and to control basic body functions such as breathing, heart rate, and body temperature. The nervous system extends through the entire body and connects every organ to the brain.

Two functional subdivisions of the peripheral nervous system are designed by autonomic and somatic nervous systems. The autonomic nervous system also known as vegetative nervous system regulates the functions of smooth muscle, glands and heart. The somatic nervous system innervates musculoskeletal structures and the sense organs of skin.

The CNS includes the human brain as the most complex of all biological systems. The mature brain is composed of near 100 billion neurons. Each neuron (nerve cell) may communicate with thousands of other neurons in complex information-processing circuits.

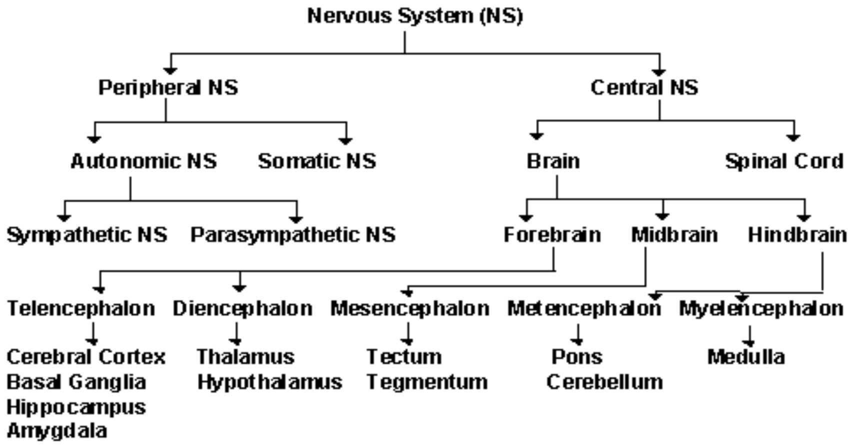

Figure 2. Nervous System

The brain is divided in three structures: forebrain, midbrain and hindbrain (see figure 2)
The cerebral cortex, also called cerebrum, is the largest brain structure in humans and accounting for about two-thirds of the brain's mass. The cerebral cortex is divided into left and right hemispheres, as well as specific areas called lobes that are associated with specialized functions.
To better understand how the brain works and their functions we need first to have a brief outlook to the development of the nervous system (neurology science).

2.1.2. THE DEVELOPMENT OF THE NERVOUS SYSTEM

2.1.2.1. Genes, Environment and Uncertainty

The individual differences in human development and organization of the brain are determined by combined genetic, environment, and uncertainty factors.
The genetic factor (or inheritance factor) has its source in the different DNA (deoxyribonucleic acid) sequences, which form the genes. Each gene, for its part, may create different compositions or polymorphisms, designated as alleles, which determinate the variations in quantity and quality of the proteins.
As supported by Sena (2016), the role of the environment in the human development, since prenatal period, can alter the expression of our genes and proteins. This

mechanism is known as epigenetic changes and allows that human beings, with similar or even identical genetic material, have different individual features.

In addition to the genetics and environments factors, there is also the uncertainty factor, known as stochastic factor, to potentiate the individual differentiation. The uncertainty factor may explain why individuals with same genetic material and exposed to the similar environment still display individual differences in the nervous system function and development and also predisposition to diseases (Sena, 2016, p.3).

In sum, genetic, environment and uncertainty factors contribute all together to the development of the nervous system and of the human brain and individual differences, usually, cannot be solely explained by genetic factors.

The human brain is about 2% of the weight of the body and it is 4 or 5 times as large of a brain of a mammal of the same size of human body.

Nevertheless, the human brain to body mass ratio does not explain by itself the essential of the neurological abilities and organization of the nervous system.

To understand the organization and function of the nervous system, it is important to know what type of cells compose the brain and how they interact and participate in the structural organization and basic functions of the nervous system.

2.1.2.2. The neurons

The main components of cerebral tissue are neurons (nerve cells) and glia cells. The neuron is considered the basic building block of the nervous system because of its extensive interconnectivity and specialize function in integration and transmission of information.

The human brain has more 80 billion neurons (Sena, 2016, p.67). OECD (2007) defines the neuron as a nerve cell body, also called soma, with a variable number of extensions (neurites), the longest one is known as an axon while the others are dendrites, which have also small branches called dendritic spines(see figure 3).

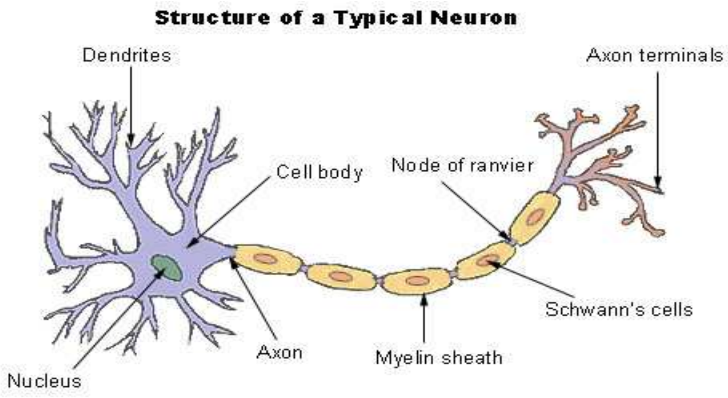

Figure 3. Structure of a Neuron

Inside of the axon, there is continuous transport of molecules and more complex structures between the cell body and axon terminals, by a mechanism called axonal transport, which is of vital importance for its normal function.

The transmission of information between neurons could be accelerated through a process called myelination. This is a process by which a compact fatty material (myelin) surrounds and insulates axons of some neurons. The myelin around the nerve fibers increases the speed at which messages can be sent. Increased myelination could be influenced by brain functional interaction with the environment, namely by extensive music instrumental practice.

The Schwann cells, which are the principal glia cells belonging to the PNS, provide myelin sheaths around axons. These cells will be addressed at section 2.1.2.4.

2.1.2.3. Neuronal connectivity and the role of the neurotransmitters

At the final of the axons and dendrites there are zones specific for contacts between neurons, known as synapses, structural and biochemically diverse. In the human brain, it can exist at least 100 billions (Sena, 2016, p.5).

Following Gazzaniga et al (2002), the communication between synapses takes place as follows: from the axon of a neuron to the dendrites and dendritic spines of another neuron, proliferating these communications through a number of synaptic transmissions resulting complex neural networks (see figure 4).

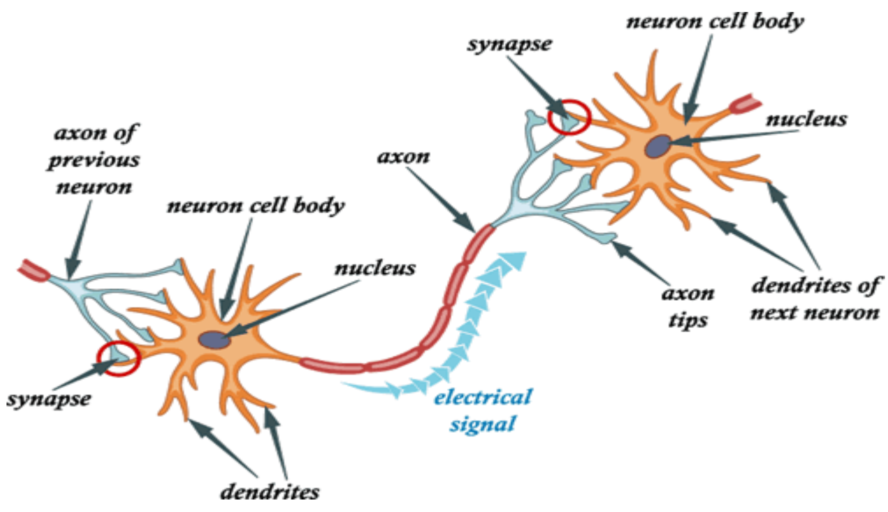

Figure 4. Synapse

The neuron that is sending information is termed a presynaptic neuron and a neuron, which is receiving information, is termed a postsynaptic neuron.

The transmission between neurons is achieved by their ability to produce electrical impulse known as action potential (or nervous impulse) that flows with the assistance of chemical facilitators called neurotransmitters. Some familiar neurotransmitters are acetylcholine, serotonin, dopamine and glutamate (Siegel and Sapru, 2011, p.137).

The brain is able to adapt to the environment through the mechanism of strengthening or weakening the existing synaptic connections. Communication between neurons is dynamic and modulated by several factors. Neurons may increase (synaptogenesis) or decrease ("pruning') their number of connections. The strength of communication between two neurons may also be altered by the amount of neurotransmitters (chemical signals) released from the presynaptic terminal of the cell production the electrical signal, by the number of receptors receiving on the postsynaptic terminal, and by how quickly the neurotransmitters is relaying information via receptors (Gibb, 2012).

Neural pathways are subjected to continuous changes during long life. Not just the number of neurons drives the brain's learning and other cognitive capacities, but especially by the richness of the connectivity between them. There is plenty of room for change as a neuron is often connected with several thousands other neurons.

2.1.2.4. The other cells of the CNS

The other non-neuron nervous cells are named neuroglia or glia cells. In the human brain the number of neuron and glial cells are about the same. However, in some areas (like the cerebral cortex) glial cells are more numerous than neurons.The glial cells are involved in maintaining the appropriate environment for normal neuronal function and provide support for the neurons.

The glia cells perform specific and essential roles in CNS, other than the neurons, and there are three group-types: astrocytes, oligodendrocytes and microglia(Sena, 2016, p.5) (see figure 5)

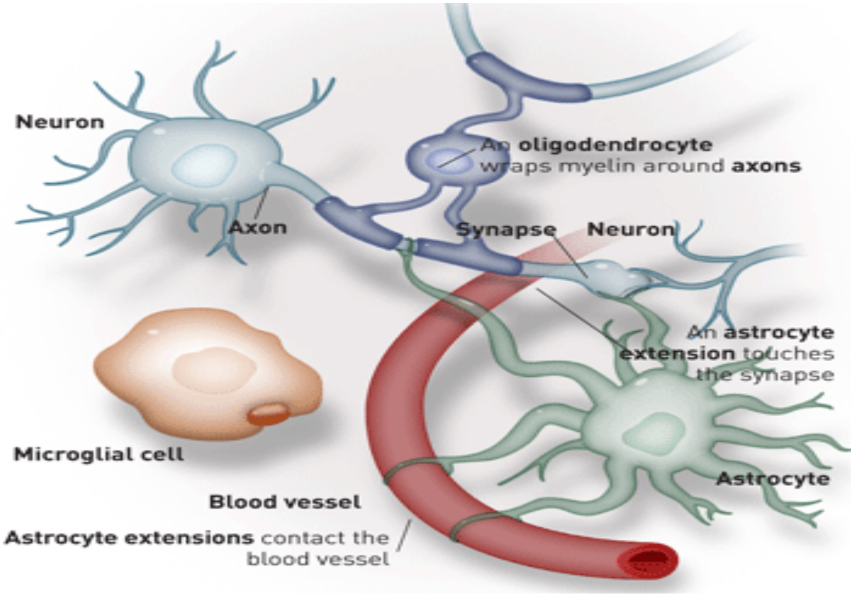

Figure 5. The Neurons and the Glial Cells

Contrary to what happens to neurons, the glia cells do not generate action potentials and they are crucial to the formation of the synapses, maintenance of some of the neurotransmitters, repair damaged tissues, elaboration of the myelin called myelination process.

2.1.2.5. The neuronal development: gestation and cerebral maturation

The large majority of the neurons and the glia cells that are part of the human nervous system are formed in the embryo, a process beginning 17 days after the conception, when the neural plate is created (Sena, 2016, p.7). The proliferation of the cells, including the oligodendrocytes, is done from the progenitor cells in a process related with the production of myelin and acquisition of specific functions and properties.

The neurons are most of them generated in the first 4 months of gestation period, and they have the capacity of renovation, process known as neurogenesis, which keep active during the long life, although at a slow pace since 20 years old. Before birth, the neural plate of the embryo evolves into a neural tube and then into a spinal cord and the brain structures, which are the cerebrum, brainstem and cerebellum (see figure 6).

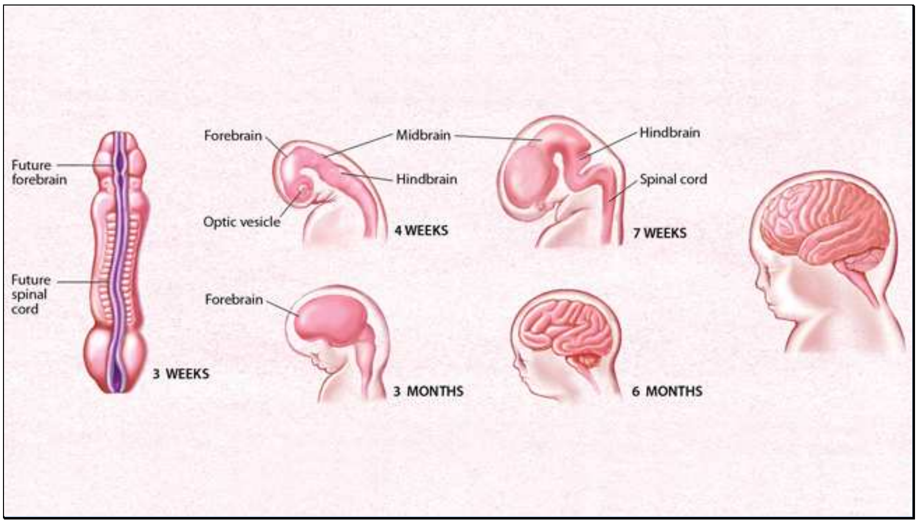

Figure 6. Neurogenesis

After birth, the baby´s nervous system has an identical structure of an adult. The brain´s maturation consists of development of the 2 hemispheres and it is followed by the huge storage of the white substance (myelin) that wraps around the axons to speed up the transmission of the signals and is responsible of the gain of the brain weight and a more efficient communication between neurons (network of synapsis).

This cerebral maturation is related also with a dynamic process of programmed cell extinction and weak synaptic contacts elimination (pruning synapsis) and creation of new neurons (neurogenesis) and proliferation of new and complex synapses, especially in the cerebral cortex area, which plays an important role on the maturation of the certain brain functions (like the executive function) (OECD, 2007).

What makes human´s CNS special, namely the cortex cerebral, is the fact that the maturation process allows increasingly complex and diverse synaptic transmissions.

According to Sena (2016), the extended maturation process, namely associated with myelination, is also supported by the development of the neurotransmitters that are responsible for the synapse communication and their dynamic change process, which only stabilizes around the 3rd decade after the birth. More than 90% of the synapses of the cerebral cortex use glutamate or GABA (amino butyric acid) as excitatory and inhibitory neurotransmitters, respectively.

These neurotransmitters are greatly responsible for the acquisition of excitatory and inhibitory synapses, and the normal development of the nervous system depends on its balanced activity. An unbalance activity of the neurotransmitters is partially associated with neurological dysfunctions or disturbances such as autism and schizophrenia.

The brain is able to adapt to the environment through the mechanism of the strengthening or weakening the existing neural networks.

In fact, the cerebral maturation process could be described as an extraordinary dynamic of chemical and cellular changes concerning either the white substance or the gray substance and the correlative synaptic changes and renovation. All these brain processes (synaptogenesis, myelination, neurotransmission, among others) are not just a product of genetic factors (derived from the correct protein synthesis), but are also the result of the interaction between the human brain and environmental factors.

2.1.3. NATURE VERSUS NURTURE ON BRAIN DEVELOPMENT

During the infancy, adolescence and adult life the brain is continually changing. This development is guided by both biology and experience. Genetic tendencies (nature) interact with experience or environment (nurture) to determine the structure and function of the brain at a given point of time.

There have been some scientific controversial views about what is the relative importance of the genetic factor (nature) versus the environment or experimental factor (nurture) concerning the brain development.

Although there is not an absolute answer for the above-mentioned question, scientific findings from brain research indicate how nurturing is crucial to shaping the brain development. To predict the human behaviour or cognitive development on the basis of genetics will be incomplete and scientific non-sustainable. According to OECD (2007, p. 26), "A gene does not activate behavior but instead consists of a sequence of DNA containing the relevant information to produce a protein". Genes affects the brain (innate factor), but research finds that brain development is a continuous result of the interaction of the genetic factor and the environment factors (acquired factor). Environmental factors conductive to improved brain functions are, among others, nutrition, physical exercise, and sleep. Even more, social-economic environment (including family ambience) may be influent on human brain differences on capacity of learning and on other cognitive functions. And we should not forget that social interaction is a constituent condition both for early development of cerebral structures and for normal development of cognitive functions. The social problematic related with the human brain is the scientific scope of the social neuroscience.

We could say that through lifetime the brain is tailored to fit the environment. Active neural connections are strengthened (when necessary) and the least active or inactive interactions of the brain with the environment are object of weakened neural connections (pruning process) (Sena, 2016).

2.1.4. THE REMARKABLE PLASTICITY OF THE BRAIN

As referred, the brain changes significantly over the lifespan as a response to environment contexts or experiences. "This flexibility of the brain to respond to environmental demands is called plasticity" (OECD, 2007, p.42).

Neural plasticity can operate in various ways at the level of the synaptic connections: some synapses may be generated or reinforced (synaptogenesis), others eliminated or deactivated (pruning) if not stimulated continuously, and so on.

Plasticity is essentially for learning and it is present through the lifetime. The degree of neuronal modification depends on the type of learning that takes place, with long-term learning leading to more profound modification, like the one that can occur on ageing adults. Combating ageing reduced function of the brain and tendencies to neurodegenerative diseases, like Parkinson, implies a process of continuous learning during all the adult life, although at a different rhythm and much more use of skills and expertise. The more opportunities to learning and keep using an active brain, the higher the chances of counteract the onset of neurodegenerative diseases.

Plasticity also depends on the period of learning, with the infants experiencing extraordinary growth of new synapses. By this reason, infancy (3 years up to 10 years) is considered a "sensitive period", or a "window opportunity" for learning and the exercise of other cognitive activities. However, there is no scientific consensus that over-stimulating a normal healthy infant has a significant beneficial effect that justified a much more spent of resources and school time.

The rejected idea of an "optimal opportunity" of learning during the infant period does not invalid the clear evidence of the key role of early childhood education and basic schooling on promoting the overall capacities to learning and a healthy development of the cognitive functions of the brain.

Sensitive periods do nevertheless exist in certain areas of learning such as language acquisition. There is an inverse relationship between age and the effectiveness of learning many aspects of language – in general, the younger the age of exposure, the more successful the learning. Thus, depriving someone access to a language until 10 years old will seriously put much more difficulties on the ability to learn.

Plasticity can be classified into two types: experience-expectant and experience-dependent. Experience-expectant plasticity describes the genetically inclined structural modification of the brain in early live and experience-dependent plasticity the structural modification of the brain as a result of exposure to complex environments over the lifespan.

Several research papers show evidence that intensive training and acquisition of expertise conducts to structural changes in the brain (experience-dependent plasticity). Music training is a particular model of neuroplasticity. And early music learning and training could exacerbate the brain plasticity and their overall benefits on general learning. These research subjects will be explored later part of the dissertation.

2.1.5. THE STRUCTURE OF THE BRAIN

The brain is organized into two major parts, the left and right hemispheres. The right hemisphere controls most activities on the left side of the body, and vice versa. Functional brain activities are repartee, specialized or predisposed in the two hemispheres: (i) right hemisphere plays a key role in spatial abilities and face recognition, for instance; and (ii) left hemisphere hosts crucial networks involved in language, mathematics and logic. The two hemispheres communicate through a band of up to 250 million nerve fibers called the corpus callosum, and there are other subsystems linking the two hemispheres. (OECD, 2007)

Music is unique in its ability to affect more than a single brain hemisphere, incorporating both the right and left sides of the brain. The left hemisphere, considered the analytical part of the brain, is responsible for the understanding of musical structure and motor skills. The right brain, often considered the more subjective and creative hemisphere, namely including the arts, focuses on the melody of music.

The cerebrum refers to cerebral hemispheres and other smaller structures within the brain, and it is composed of the following sub-regions: limbic system, cerebral cortex, basal ganglia, and olfactory bulb.

2.1.5.1. The cerebral cortex

The cerebrum hosts the cerebral cortex, a 2-4 mm thick multi-layered sheet of cells on the surface of the brain that covers 2 000 square centimeters. (OECD, 2007, p.39) The cerebral cortex comprised a large proportion of the neurons of the human brain and is mainly brought into play for higher-order functions. The cerebral cortex is comprised of grey matter as well as white matter. Grey matter consists mainly of nerve cell bodies and dendrites. White matter consists primarily of axons that connect various grey matter areas of the brain.

The major subdivisions of the cerebral cortex are: the frontal lobe, the parietal lobe, the occipital lobe and the temporal lobe (see figure 7).

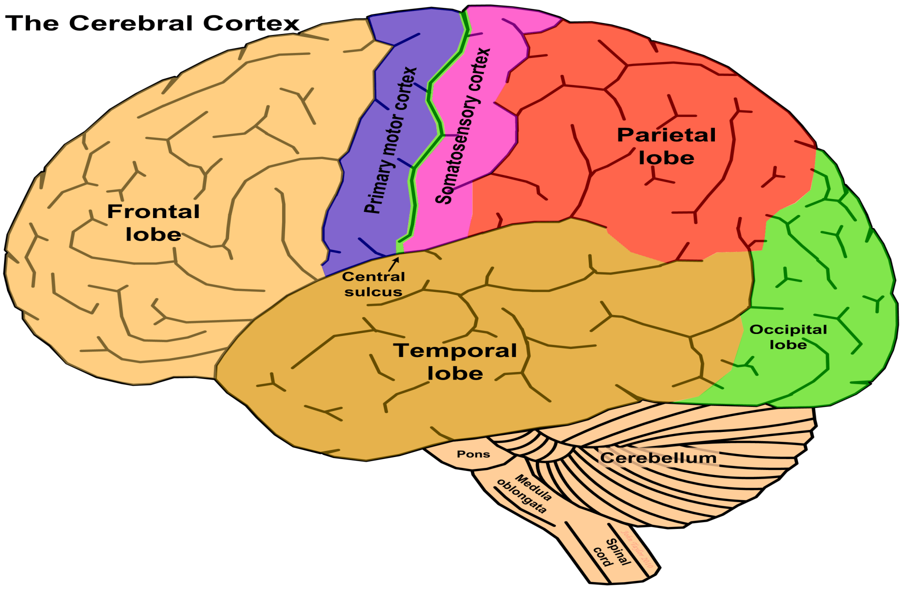

Figure 7. The cerebral cortex

The specific functions of each lobe are the following:

According to the OECD (2007, p.41), "The frontal lobe is associated with many high-order cognitive functions including planning, judgment, memory, problem-solving and behavior. In general, the frontal cortex has an executive function, controlling and coordinating behavior". Damage to or immaturity of the frontal lobe could be associated with social undesirable behavior. As the human brain matures to adulthood, there is a progressive myelination from the back to the front of the brain. Given that myelinated axons carry impulses faster than unmyelinated ones, brain maturity is associated with better executive functioning while demyelination (loss of myelin) is associated with diseases such as multiple sclerosis.

> The parietal lobe areas have been associated with mathematics learning. The parietal lobe also integrates sensory information and visuospatial processing. The angular gyrus sub-area is associated with language and cognition including the processing of metaphors and other abstractions. […] The temporal lobe is related to auditory processing and hearing, including speech, which is particularly the case in the left temporal lobe. The left fusiform gyrus is part of the temporal lobe and is associated with word recognition, number recognition, face recognition and processing colour information The occipital lobe is located

at the back of the brain above the cerebellum. In the interior portion of this lobe is the primary visual cortex. The occipital lobe is associated with visual processing, colour discrimination and movement discrimination (OECD, 2007, p.41).

2.1.5.2. The functional brain

The brain carries on different information processing tasks (functions) in different parts of the brain – the principle of functional localization. Each part of the brain operates different tasks and is composed of numerous inter-linked neurons, with neurons serving the same or similar functions connected with each other in assemblies. (OECD, 2007) (see figure 8).

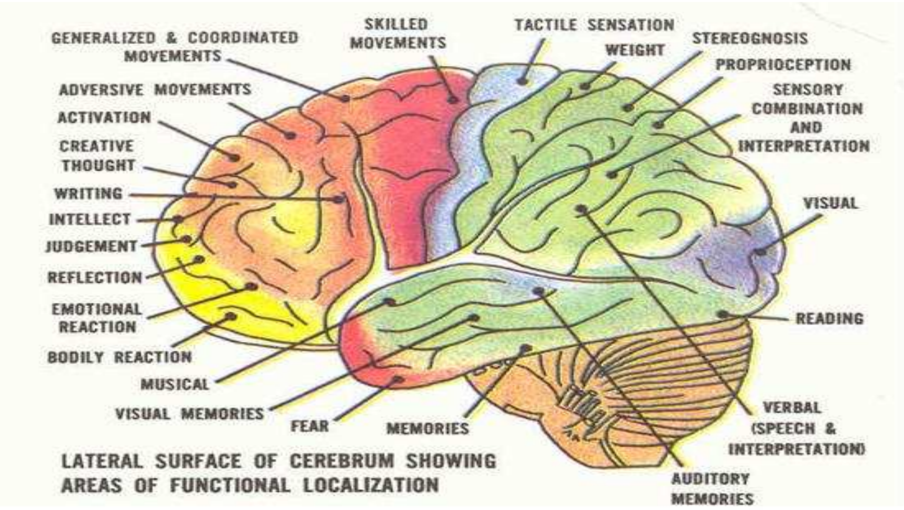

Figure 8. Brain areas functions

Brain areas are highly specialised, serving very specific functions or sub-functions, but when it is necessary to provide a given cognitive task the neuron organizations is able to establish a close cooperation, called cognitive networks. According to OECD (2007, p.252) cognitive networks in the brain are involved in processes such memory, attention, learning, and remembering. In particular, the ability to practice music demands a complex network of functional areas of the brain, like auditory cortex, motor cortex, sensory cortex, corpus callosum and limbic system, the last one associate with the emotional brain.

In summary, neuroscience has the potential to provide explanations how the brain works when learns and practice music. Music practice affects the neural connections and involves different functions of the brain and practically every cognitive function. Music is essentially emotion and the artistic expertise to express that emotion. Music activity involves wide networks of central nervous system, stimulates the plasticity of the brain, and provides specific capacities and skills.

2.2. MUSIC AND THE BRAIN

2.2.1. THE CEREBRAL BASIS OF MUSIC

Music is present in an unusual number of human activities. "Whenever humans come together for any reason, music is there: weddings, funerals, graduation from college, men marching off to war, stadium sporting events, a night on the town, prayer, a romantic dinner, mothers rocking their infants to sleep, and college students with music as a background" (Levitin, 2006, p.6). In the same way, music can be seen with the function to increase social cohesion and as a first language of communication between parents and their infants.

> Across cultures, infants are exposed to music from the beginning in a social context as caregivers sing to them. (…) music evolved to promote social bonds and group cooperation, which was particularly necessary in order for parents to protect and invest in infants who remained immature for a long period time. (Trainor, Hannon, 2013, p.434-5)

Even more, music can be seen as a natural or biological human activity:

> All of us are born with the capacity to apprehend emotion and meaning in music, regardless of whether we understand music theory or read musical notation. Without conscious effort, the human brain is able to translate spectral and temporal patterns of acoustic energy into music's basic perceptual elements: melody, harmony, and rhythm. (Tramo, 2001, p.54)

However, there are some few individuals without the ability to recognize/reproduce musical tones or enjoy the music. This brain musical disorder is called amusia, which can be of congenital origin or acquired sometime later in life as a result of brain damage (Sena, 2016).

Not less relevant, music evokes emotions and subsequent feelings and listening or practicing music engage different areas of the human brain activity, as well as promotes musical skills and activates correlative neural subsystems. Neuroscience research supported on neuroimaging techniques to investigate patients with local brain damage or normal individuals, has been able to find out that music can change the state of large-scale neural systems of the human brain.

That neural changes are not just confined to brain sectors related to auditory and motor processing, but also occur in regions connected with regulation of homeostasis life processes, including those related to emotions and feelings, namely the hippocampus, that is known to play a significant role in learning and memorizing and is likely to be one of the mechanisms through which music produces its affective responses (Habbibi & Damasio, 2014).

For the neuroscientists there is plenty evidence that music has neurobiological foundations behind their historical origins as a sociocultural phenomenon or an artistic expression of human being living in society.

> Music may have prevailed in human history largely because of its contribution to well-being and relatedly to survival. This possibility is entirely compatible with the intellectually and culturally autonomous status of elaborate varieties of music creation and listening (Habbibi & Damasio, 2014, p. 94).

Defining music, a universal and complex phenomenon, with multiple instrumental and cultural expressions, and different people involved, is not an easy task. Edgar Varèse emphasizes the idea of music, as “organized sound” in reference to is own musical aesthetic conception (Landy, 2007, p.7). Accepting this brief definition, it is important to identify the basic elements or attributes of the sound.

> The basic elements of any sound are loudness, pitch, contour, duration (or rhythm), tempo, timbre spatial location and reverberation. Our brains organized these fundamental perceptual attributes into higher-level concepts – just as a painter arranges lines into forms – and these included meter, harmony, and melody (Levitin, 2006, p.14).

Musical basic terms could be summarized as follow: (Levitin, 2006, p.14-16):

- Tone is a discrete sound (or note if written on a page or score of music).
- Pitch is purely a psychological construct, related both to the actual frequency of a particular tone and to its relative position in the musical scale. It provides the answer to the question “What note is that?” (“It’s a C-sharp”).
- Rhythm refers to the durations of a series of notes, and to the way they group together into units.
- Tempo or meter refers to the overall speed or pace of the piece.
- Contour describes the overall shape of a melody, taking into account only the pattern of “up” and “down”.
- Timbre is that which distinguishes one instrument from another – say trumpet from piano – when both are playing the same written note. According to Lapp (2003, p.28), “the difference in intensities of the various overtones produced gives each instrument a characteristic sound quality or timbre, even when they play the same note”.
- Loudness is a purely psychological construct that relates (nonlinearly and in poorly understood ways) to the physical amplitude of a tone.
- Spatial location is where the sound is coming from.
- Reverberation refers to the perception of how distant the source is from us in combination with how large a room or hall the music is in. It is the quality that distinguishes a pleasing sound from a poor sound that comes from the source of music in a concert hall or other musical place.

These attributes (or dimensions of the music) are separable. The difference between music and a random or disordered set of sounds has to do with the way these fundamental attributes combine, and the relations that form between them. When these basic elements combine and form relationships with one other in a meaningful way, they give rise to the following concepts such as (Levitin, 2006, p.16):

- Melody is the main theme of a musical piece, the part that you sing along with, the succession of tones that are most salient in your mind;
- Harmony is about how the pitches are organized into groups;

- Meter is usually perceived as a regular flow of the beat;
- Key is related with the hierarchy of the tones in a musical piece.

> Among all the attributes of music, pitch can be considered the most essential for music of the acoustic characteristics, being a central organization principle for virtually any imaginable musical culture (Perry, 2002, p.244).

To be more precise, pitch is related to the frequency or rate of vibration of a string, column of air, or other physical source. If a string is vibrating so that moves back and forth sixty times in one second, we say that it has a frequency of sixty cycles per second. The unit of measurement, a cycle per second, is often called Hertz (abbreviated Hz)" (Levitin, 2006, p.19).

Some neuroscientists have been given importance to distinguish an individual with normal pitch perception from another one with absolute pitch. Absolute pitch (AP) could be defined as: "a rare ability possessed by some individuals who can name the pitch of a musical tone, or sing a named pitch on demand, without refereeing to any other sounds" (Perry, 2002, p. 243).

The ability to possess AP or not, should not be dramatized as people differ in their ability to detect changes of frequency and training and cultural differences may explain a large part of individuals differences. Most important,

> All of us have the innate capacity to learn the linguistic and musical distinctions of whatever culture we are born into, and experience with the music of that culture shapes our neural pathways so that we ultimately internalize a set of rules common to that musical tradition (Levitin, 2006, p.26).

Another relevant research question is related with the brain's regions involved in music processing. First of all, it is important to have an overview of the acoustic assimilation of the sound by anatomical human body and the neural mechanisms associated with the processing of the sound in the brain.

> A sound begins as a wave of vibrations that is picked up by the trumpet-shaped outer ear. Vibrations travel through the middle ear before being converted into electrical signals by the organ of Corti, which is the main organ of hearing and is located in the cochlea. There are thought to be several nerve pathways that sound impulses take through the brainstem to reach the thalamus and primary

auditory cortex for processing into the conscious perception of sound (Carter, 2009, p.93).

2.2.2. MUSICAL HEMISPHERIC SPECIALIZATION AND MUSIC CENTERS

Specifically speaking about "organized sound" or music there has been a long scientific debate about the eventual existence of a hemispheric predominance or music centers on music processing.

Where and how the brain processes the music poses neuroanatomical questions related with the role of the right and left hemispheres, the parietal lobes (and their sub-regions), and other main regions of the brain involved in the perception and production of music.

"The emerging picture is complex but coherent, and moves beyond older ideas of music as the province of a single brain area or hemisphere to the concept of music as a "whole-brain" phenomenon. Music engages a distributed set of cortical modules that process different perceptual, cognitive and emotional components with varying selectivity" (Warren, 2008, p.32).

The traditional view puts music perception or processing on the same hemisphere of the arts and imagination – the right-brain hemisphere, by opposition to the left-hemisphere with more inclined to analytical tasks. But this view of absolute or exclusive right-hemispheric specialization on processing music seems to not have much scientific support. Otherwise, it seems more evident that there is a participation of both hemispheres and a necessary coordination between them.

> Writers, businessman, and engineers refer to themselves as left-brain dominant, and artists, dancers, and musicians as right-brain dominant. The popular conception that the left brain is analytical and the right brain is artistic has some merit, but it is overly simplistic. Both sides of the brain engage in analysis and both sides in abstract thinking. All of these activities require coordination of the two hemispheres, although some of particular functions involved are clearly lateralized (Levitin, 2006, p.122).

Spoken language processing seems to have some common brain features with music processing, and for some musicians or scientists there is a "language of music" or a "common grammars of music and language" as, for instant, defended by the composer and conductor Leonard Bernstein, and referred by Michael Trimble (Trimble, 2007, p.

122/123). This common feature explains the left side use of the brain (or the left lateralization) on processing some attributes of the music:

> Local features of spoken language, such as distinguished one speech sound from another, appear to be left-hemisphere lateralized. The overall contour of a melody – simply its melodic shape, while ignoring intervals – is processed in the right hemisphere, as is making fine discriminations of tones that are close together in pitch. Consistent with its language functions, the left hemisphere is involved in the naming aspects of music – such as naming a song, a performer, an instrument, or a musical interval. (…) There is also new evidence that tracking the ongoing development of a musical theme – thinking about key and scales and whether a piece of music makes sense or not – is lateralization to the left frontal lobes.(Levitin, 2006, p.122-123)

Much more relevant is the process of hemispheric lateralization associated with the practice of music:

> Musical training appears to have the effect of shifting some music processing from the right (imagistic) hemisphere to the left (logical) hemisphere, as musicians learn to talk about – and perhaps think about – music using linguistic terms (Levitin, 2006, p. 123).

Music training has also specific neurological activity:

> At a neural level, playing an instrument requires the orchestration of regions in our primitive, reptilian brain – the cerebellum and the brain stem – as well as higher cognitive systems such as the motor cortex in the parietal lobe and the planning regions of our frontal lobes, the most advanced region of the brain (Levitin, 2006, p.67).

In summary, the traditional view that the musical hemisphere is the right one should be replace by the more consistent view that our perception or processing of music occurs bilaterally in both hemispheres – with which one as their specific role on processing the different attributes of music. The right auditory cortex is essential for perceiving pitch and some aspects of melody, harmony, timbre, and rhythm (Tramo, 2001). The left auditory cortex seems more active in the perception of melodic intervals and appears specialized for rapid temporal processing (specially associated with music training or practice), as well as on musical language interpretation by musicians (Levitin, 2006). The corpus callosum have the crucial role to assure the hemisphere connections and the

brain's contralateral organization, such as the left hemisphere controls motor output for the right side of the body, and vice-versa (Merrett & Wilson, 2011, p.128).
Even more, there is "no music center" in the brain. All the brain structures participate in a complex and integrative processing of music:

> Producing music is a complex task, requiring finely-tuned motor movements, highly developed sensory abilities (in auditory, visual, tactile, and kinesthetic modalities), the integration of motor and sensory information to monitor and correct performance, and higher-order executive and attention functions (Merrett & Wilson, 2011, p. 125).

Processing the music involves the four lobes of the brain – frontal, parietal, occipital and temporal - and their sub-regions in different ways and specifics tasks associated with the perception of distinct music attributes.
According to Merret and Wilson, the processing of sound occurs first in the ear and the brainstem and after the auditory cortex, located in the temporal lobes. Primary cortex and secondary areas around it are important for frequency, pitch and music perception. The right auditory cortex is particularly involved in processing for timbre and fine-grained pitch discrimination and also on the perception of melodic contour. The opposite hemisphere seems to be more specialized on the perception of rhythm, melodic intervals and on rapid temporal processing (Merrett & Wilson, 2011, p.129).
The next step consists in playing the musical instrument, which involves the primary (hearing, vision and somatosensory) and secondary sensory domains for kinesthetic and tactile feedback. Together with the motor cortex and cerebellum, music production is possible, but there is also a need of frontal lobes, for their working memory, planning and monitoring.
This summary description gives a general view about the cerebral basis of music processing or production, and confirms that almost all the brain regions are subject to the music-induced experience, which gives place to structural neural plastic changes and some functional brain differences between musicians and nonmusicians.

2.2.3. MUSIC AND NEUROPLASTICITY

As we have seen in Part 1 – Introduction to Neuroscience, the brain is far from being immutable since birth in relation to number of cells and neural connections. By contrary, the brain changes significantly over the lifespan as a response to environment contexts or experiences. In reality, "the brain, it seems, has a certain ability to repair itself and continue to grow and develop through life" (Carter, 2009, p.193).

Plasticity is one of the most remarkable features of the human brain. Cellular elements are engaged into neural networks that assure functional stability but at the same time they are sufficiently plastic to adapt their functional connectivity to shift demands. Merrett and Wilson (2011) define neuroplasticity as the ability of the brain to change its structure and function during learning and memory or in response to changes in the environment. Dynamically changing neural networks to environmental pressures or to learning and memory challenges through the lifespan is the essence of the human brain neuroplasticity. As a result of differences both in genetic characteristics and in the environmental experiences, brains are shaped differently. Brain's capacity to adjust to environmental experiences (nurture factor) can surpass the relative importance of pre-existing abilities (genetic or nature factor).

A distinction between structural and functional neuroplasticity should be done. Structural neuroplasticity is related to macro structural changes in brain (size, shape, density, and connectivity) that can be seen in neuroimaging techniques. Functional neuroplasticity refers to changes in brain processing (increases or decreases in activation) (Merrett and Wilson, 2011).

Learning and brain plasticity are fundamental properties of the human nervous system. The brain changes in response to the opportunities to learn and from experience-dependent neuroplasticity. The human brain possesses the ability to acquire virtually any skill given appropriate training and other presupposes.

As a result of decades of neuroscience research, a set of ten core principles of neuroplasticity are applied to experience-dependent on learning or relearning (on brain rehabilitation from damage) has been defined by Kleim and Jones (2008).

Table 1. Core Principles of experienced-dependent neuroplasticity

Core principles of experienced-dependent neuroplasticity
(Kleim & Jones, 2008)

Principle	Description
1.Use it or Lose it	Failure to drive specific brain functions can lead to functional degradation.
2. Use it and improve it	Training that drives a specific brain function can lead to an enhancement of that function.
3.Specifity	The nature of the training experience dictates the nature of the plasticity.
4. Repetition matters	Induction of plasticity requires sufficient repetition.
5. Intensity Matters	Induction of plasticity requires sufficient training intensity.
6. Time Matters	Different forms of plasticity occur at different times during training.
7. Salience Matters	The training experience must be sufficiently salient to induce plasticity.
8. Age Matters	Training-induced plasticity occurs more readily in younger brains
9. Transference	Plasticity in response to one training experience can enhance the acquisition of similar behaviors.
10. Interference	Plasticity in response to one experience can interfere with the acquisition of other behaviors.

These principles of neuroplasticity could be applied to learning and memorizing processes, sports, arts and music training, among other acquisitive or adaptive human life experiences, and might influence strategic educational issues.

In particular, neuroscientists have elected music training as an ideal model for examining experience-dependent neuroplasticity, due to their unique variation and training experiences, complex task and specialized skill acquisition. Some decades ago, the dynamic piano experience has been objected of this sui-generis appreciation. In this topic, Smith, cited by Pascual-Leone (2001) paraphrases:

> "The most intricately and perfectly coordinated of all voluntary movements in the animal kingdom are those of the human hand and fingers, and perhaps no other human activity do memory, complex integration, and muscular coordination surpass the achievements of the skilled pianist"(cited from Smith, from Fish to Philosopher, 1959, p.205).

During the last two decades, there have been a considerable number of studies focused on musical training and neuroplasticity, and correlated structural and functional brain's

changes. The titles of some of the most representative studies in the neuroscientific field of the neuroplasticity induced by music training are very appellative to their purpose and significance:
"The Brain that Plays Music and is Changed by It" (Pascual-Leone, 2001);
"The musician's brain as a model of neuroplasticity" (Münte, et al., 2002);
"Music, the food of Neuroscience" (Zatorre, 2005);
"Music drive brain plasticity" (Jäncke, 2009);
"Music Making as a Tool for Promoting Brain Plasticity across the Life Span" (Wan and Schaulg, 2010);
"A Little Goes a Long Way: How the Adult Brain is Shaped by Musical Training in Childhood" (Skoe and Krauss, 2012);
"Musicians and music making as a model for the study of brain plasticity" (Schaulg, 2015).

In almost all of these and other similar studies, the core principles of experiment-dependent neuroplasticity can be applied to music training experience. Some synthesis has been done about their suitable application to music training:

> In fact, training in music making has been hailed as an ideal model for examining experience-dependent neuroplasticity as it embodies many of the prerequisites for inducing neuroplasticity; repetition of, intensity of an specificity of training against a background of high emotional salience and reward (Wilson, 2013, p.142).

When applying the core principles of experience-dependent plasticity to music training, the first principle (use it or lose it) explains that this higher skill human activity requires the frequent use of some proper neural circuits associated with specific musical brain functions. Failure to support the performance activity of those neural circuits for an extended period of time leads to functional degradation. The second and third principles of neuroplasticity (use it and improve and specificity) concern about the importance of skilled and frequent music practicing to induce more plasticity (dendritic growth and synaptogenesis) with specific brain regions and improved sensory-motor functions necessary to achieve quality in performance.
The principles of repetition, intensity and time are important to achieve higher quality performance, and assure more complex tasks on music performance. Plasticity induced

by repetition is crucial to consolidate a lasting neural change (skill instantiation). Behind the repetition, the importance of intensity is demonstrated in the way when stimulation during training is weak there may not be enough synaptic connections required for music performance. Plus, time is a variable to consider in improving the quality of music training, as certain forms of plasticity that may be dependent of other previous training.

The referring principles of experiment-dependent neuroplasticity when applied to instrumental music playing helps to explain how the human brain has to be able to achieve exceptional musical performance on complex movements that requires the integration of sensory and motor tasks and high speed control under continuous auditory feedback. That’s the case of the piano performing on one variation of the 6th Paganini-Etude by Frank List. “Performing music at a professional level is arguably the most complex human accomplishments. A pianist, for example, has to bimanually coordinate the production of up to 1,800 notes per minute” (Muntë et al., 2002, p.473).

More recent findings suggests that the core principles of experiment-dependent neuroplasticity of Kleim and Jones (2008), when applied to music training should be moderated/complemented with other variables like the age at commencement of training, the musical instrument and type of training, the differences between professional musician and amateur musician concerning frequency/ intensity of practice and other parameters, the ability or the absence of absolute pitch (AP), and other variables like differences on genetics, brain’s gender, personality engagement and environmental auditory (Gruber et al, 2010; Merrett et al, 2013; Wilson, 2013; and Schaulg, 2015).

The following figure constitutes a schematic representation of moderating variables of music-induced neuroplasticity and their interactions (Merrett et al, 2013, p. 5).

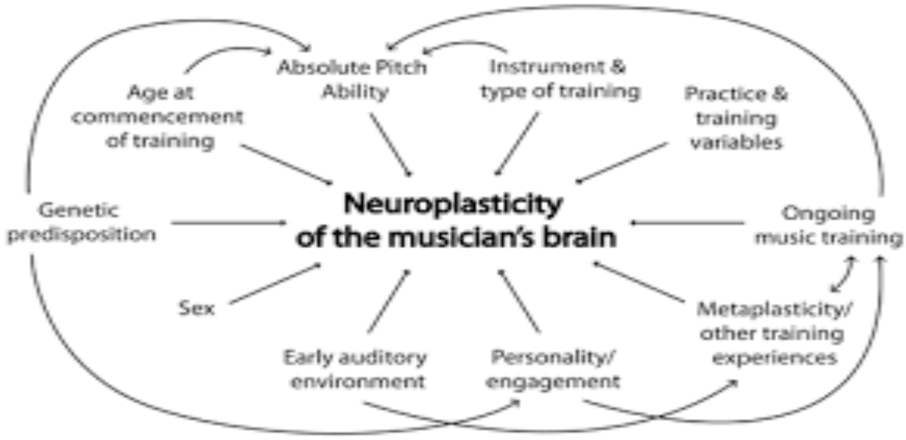

Figure 9. Neuroplasticity of Musician´s Brain

A considerable number of research findings on music neuroscience highlight the importance of the age of commencement on music training for neuroplasticity and ability to get absolute pitch (although this would not strictly necessary to becoming a musician or an instrumental player). According to Merrett et al, "those musicians who begin training prior to age seven may show greater capacity for neuroplasticity changes than those who take up an instrument later in childhood or in adulthood" (Merrett et al, 2013, p. 2). Given the theme's importance and possible implications to ideal periods of music's education initiation, we will resume to it on part 2.2.5 of this dissertation.

The neuroplasticity model of the musician developed by Merrett, Peretz and Wilson (2013), has been designed to highlight a number of variables that appear to moderate the relationship between music training and brain structure and function, which constitutes the basis of a substantive literature about the neuroplasticity induced by music and correlative brain differences between musicians and nonmusicians (see part 2.2.4).

However, "the brain that play's music and is changed by it" (Pascal-Leone, 2001) depends not just on the age of beginning but also on the intensity, extension and technical training, and even on the nature of the musical instrument.

For instance, "different musical instruments provide unique sensory and motor experiences and can lead to differences in the type and location of neuroplastic changes" (Wilson, 2013, p.143). Additionally, extensive practice and instrumental specialization leads to an extension hand area in the motor cortex and to a growth in grey matter density corresponding to more and/or an increase of neurons in the same area. Similar effects of specialization have been found with professional pianists and violinists concerning the increase of the size of the corpus callosum, especially those who have started training prior to seven years old (Gruber et al., 2010).

Those variables should be useful to discriminate the degree of expertise of an individual with music training – professional musician, amateur musician and nonmusician – which seems important to moderate the findings of some studies that merely oppose musicians' brains to nonmusicians' brains, without taking in consideration the non-expert musicians or amateur musicians.

In reality, among other variables to discern a professional musician from an amateur musician are the level of skill or expertise attained that depends on the beginning age of training; the type of training received, the amount of time practicing (hours per day or week) and the lifetime accumulated of practice (years). It is supposed that professional musicians make the majority of their living from music, by opposition to amateur musicians who normally spent fewer hours on training and has less accumulated hours of practice. Nonmusicians could be defined as those without the ability to play an instrument or have no formal music training. They could however be extremely educated in music listening (passive listening).

The distinctions between professional musicians, amateur musicians and nonmusicians are crucial to characterize the neuroplasticity effects induced by music training, and subsequently anatomical and functional brain changes. Playing a musical instrument without being a professional does not exactly produce the same neuroplasticity effects on brain as it would happen with a professional musician.

However, considering the principles of experiment-dependent neuroplasticity of Kleim and Jones (2008) and the model defined by moderating variables of music-induced neuroplasticity (Merrett et al, 2013), combined with a large body of neuroscientific literature on music training and their findings on cerebral effects, we carefully proposed that music training developed by non-professional musicians has been able to induce neuroplasticity and structural/functional brain changes with positive effects on brain development and improved capacity on learning. But this would be more accurately on the assumption that music learning should begin at early ages, and would be improved or consolidated during lifespan by a continuous, specific and consistent technical training (use it and improve it, plus other principles of neuroplasticity applied to music training).

2.2.4. BRAIN DIFFERENCES BETWEEN MUSICIANS AND NONMUSICIANS

Music practice involves many areas of the brain. Different regions of the brain responds to the tasks required to musical training, and the brain alters itself with a consistent instrumental music practice.

With the advent of modern imaging techniques, neuroscience researchers have been able to localize the brain areas involved in neuronal processing of music. The brain stimulation that comes from the recurrent processing of music (experience-dependent neuroplasticity) leads to some cerebral differences between musicians and nonmusicians.

In reality, music learning and instrumental practice provides an opportunity to study the brain structure and functionality in response to this unique cerebral experience-dependent (Schaulg, 2001).

Musical training shapes the brain in response to the fact that music processing requires a complex combination of motor, auditory, visual, memory and emotional skills (Hyde et al., 2009 and Barrett et al., 2013).

The training processing of music and their correlate development of musical brain skills makes musicians as a model to study the neural changes in human brain (neuroplasticity) that result from an experience-stimulus (Münte et al, 2002).

As described in the previous part, the musician’s brain is subjected to numerous, complex and diverse musical activities that induce neuroplasticity in different parts of the brain detected by neuroimaging methods.

The following table gives a general idea about the core brain regions associated with musical activity (see table based on Levetin and Tirovolas, 2009, p. 212).

Table 2. Brain regions and music activities

Core Brain Regions	Musician´s activities
Motor cortex – the part of the brain's cerebrum in the frontal lobe that is involved in movement and muscle coordination.	Movement, foot-tapping and playing an instrument
Sensory cortex – the part of the brain's parietal lobe concerned with receiving and interpreting sensory information from various parts of the body.	Tactile feedback from playing an instrument
Auditory cortex - Part of the brain's temporal lobe. This is the area of the brain responsible for hearing. Nerve fibres extending from the inner ear nerve impulses generated by sounds into the auditory cortex for interpretation.	The first stages of listening to sounds, the perception and analysis of tones
Prefrontal cortex – the area of the cerebrum located in the forward part of the frontal lobe, which is thought to control higher cognitive processes such as planning, reasoning, and social cognition.	Creation of expectations; violation and satisfaction of expectations
Visual cortex – The area of the cerebrum that is specialized for vision. It lies primarily in the occipital lobe, at rear of the brain, and is connected to the eyes by the optic nerves.	Reading music, looking at a performer's music (including one's own)
Corpus callosum – bundle of nerve fibres in the longitudinal fissure of the brain that enables corresponding regions of the left and right cerebral hemispheres to communicate.	Connects left and right hemispheres
Hippocampus – A primitive brain structure located in the brain that is involved in memory and learning.	Memory for music, musical experiences, and contexts
Nucleus Accumbens – Located in the striatum, plays a central role in the reward circuit.	Emotional reactions to music. The striatum is related with the production of dopamine and so is related with motivation.
Amygdala – is an almond-shaped set of neurons located deep in the brain's medial temporal lobe. Play a key role in the processing of emotions, and forms part of the limbic system.	Emotional reactions to music
Cerebellum – A brain structure located at the top of the brain stem that coordinates the brain's instructions for skilled, repetitive movements and helps to maintain balance and posture.	Movement such as foot-tapping and playing an instrument. Also involved in emotional reactions to music

Some of the most salient differences between the brain of the musicians and nonmusicians can be found in the corpus callosum, motor cortex, and cerebellum.

The corpus callosum, which is the largest white matter structure in the human brain, assumes a vital function on the music training processing, connecting the two hemispheres. There is some evidence that the corpus callosum is subjected to a greater neural activity induced by music. Instrumental training requires an increase and faster interhemispheric exchange in order to perform bimanual complex motor sequences, and this ability suggests the reason of larger corpus callosum in musicians, when compared with nonmusicians (Schaulg, 2001). It has been also supported by other researchers that interhemispheric interactions contribute to the acquisition of bimanual skills, which is a fundamental ability in playing a musical instrument. The greater interconnectivity between the hemispheres, the larger is the size of the corpus callosum. Gender, age, and motor training in addition to the size of the corpus callosum add influence on interhemispheric interactions (Takeuchi et al., 2012).

Corpus callosum anatomical differences between musicians and nonmusicians seem to be larger in musicians that start to train before the age of 7. This is related with the functional maturation of the corpus callosum (and associated with myelination cycle) that may occur through childhood until adolescence (Schaulg et al., 1995). In line with this observation, “there is a general consensus that movement control and motor coordination as well as intermanual transfer of sensorimotor information improves gradually from ages 4 to 11 years, an age span coinciding with callosal maturation” (Schaulg, 2001, p.284).

In relation to music training, relevance should also be given to the type of instrument and/or training regimes that could have important implications on the structural brain differences among the musicians and between musicians and nonmusicians (Vollmann et al., 2014). Furthermore, recent research findings provide evidence that early music training (before the age of 7 years) could result in changes in white-matter structure of the corpus callosum and correlated additional plasticity in motor and auditory connectivity that “may serve as a scaffold upon which ongoing experience can build” (Steele et al., 2013).

Another core brain regions mobilised by the practice of music, the motor cortex is specially activated by the movement associated with playing an instrument, namely by exceptionality of the movements of both hands and associated dexterity.

Furthermore, “… we asked a fundamental question whether consistent and in most cases daily practice of complicate bimanual finger sequences led to macrostructural changes in the human motor cortex if this training occurred during a critical period of the brain development” (Schaulg, 2001, p. 286).

It should be noticed that to achieve a high level of music expertise requires a more dynamic and plastic motor cortex and also higher coordination with other cortex brain functions. In reality, performing music at a high professional level makes difference on the required sensorimotor coordination and corresponded intensity of the brain neural plastic adaptions.

The cerebellum is at the back of the brain and the main functions are the coordination of body movements through integrated control of muscles, including balance and posture. Given to these relevant functions, the cerebellum has a large surface of grey matter and a very high density of neurons and neural connections (it represents 10% of the brain’s total volume but accounts for over 50% of its total neurons).

Music training involves the vital role of the cerebellum in movement coordination, timing of sequential movements and other cognitive functions, and the evidence of the additional intense neural activity on the cerebellum induced by musical practice may explain the relative cerebellum's volume difference between male musicians and non-musicians in favour of the first one by around 5% (Schlaug, 2001).

Other similar study confirms a significant difference in absolute and relative cerebral volume between male musicians and non-musicians and it also finds a positive correlation between the relative cerebellar volume of the musicians and the intensity of musical training through life (Hutchinson et al, 2003).

In summary, music learning and training requires a complex and multimodal integration of cerebral activities, like sight-reading, learning and memory, pitch and tonal perception, manual dexterity and tactile feedback, motor-sensory coordination, visual music performance and emotional reactions to music.

Expressing the complexity and enriched experience-dependent for the brain development "… music making draws on a range of highly developed and well-integrated sensory, perceptual and motor skill, as well emotions, memory, and higher order cognitive and attentional functions" (Wilson, 2013, p. 141).

In particular, when selected some of the relevant scientific literature on the brain differences between musicians and non-musicians, it should take in consideration development factors in music training and their different results regarding the distinction between professional and non-professional musicians.

Developmental factors to individualize the brains of musicians from the nonmusicians, includes factors like age when music training begins, the quality of learning, or the extent and intensity of training of the musician.

Furthermore, there is some evidence that the degree of musical expertise, provided by extensive, intensive and qualitative music training, modulates higher order brain functioning (Oechslin et al, 2013). This expertise reinforces the brain plasticity and functionality differences between the professional musicians (experts) and amateur musicians or even more with nonmusicians.

Finally, a particularly developmental factor on musical training that could have a relevant impact on musicians' brain features is possible related with the occurrence of sensitive periods on experienced-dependent music learning and practice.

2.2.5. MUSICAL TRAINING AND SENSITIVE PERIOD

Although neuroplasticity is not an occasional state of the human nervous system but rather a normal biological predisposition state system throughout the lifespan, there has been sufficient scientific evidence that the capacity for neuroplasticity peaks during certain sensitive periods, depending on the nature of the experiment-dependence to environment.

The term “sensitive period” is a broad term that applies whenever the effects of experience on the brain are unusually strong during a limited period in human development brain (Knudsen, 2004, p.1412).

Human brain development exhibits changes with the age. During the late childhood and adolescent until half of all synapses are lost from the neocortex and such structural change is sometimes associated with the loss of functional plasticity. So, a sensitive period could represent a window of opportunities to maximise the ability to change the behavior based on experience or to learn more easily and with greater proficiency. In terms of Education, the strongest evidence for sensitive periods is in language acquisition and music. These skills are likely to be more effectively acquired if learning starts between five and ten years old (Thomas and Knowland, 2009).

Given the current literature review, age commencement of music training appears to be one of the most important variables of music induced neuroplasticity. Beginning music training during a sensitive period, for instance before the age of 7 years, may have greater effects on brain structure and behavior than start training later in life (Steele, et al., 2013).

Another study finds that musicians that began music training before age of seven reveals higher plasticity and greater adult motor performance, than those musicians, with similar levels of practice and experience, but that start training after the age of seven. The study confirms “the idea that there may be a sensitive period in childhood where enriched motor training through musical practice results in long-lasting benefits for performance later in life” (Watanabe, et. al, 2006). To enforce this position, another study supports the existence of a sensitive period, around age of seven years, and after that music-induced structural changes and learning effects are less pronounced (Habibi and Besson, 2009).

Learning to play a musical instrument in childhood can result in long-lasting positive effects on the adult brain, even when the instrumental training experience occurs just for a few 3 years and stops after that. The title “A Little Goes a Long Way: How the Adult Brain is Shaped by Musical Training in Childhood” (Skoe and Kraus, 2012), suggests the relevance of music training in childhood and the results (obtained from tests on adults) have implications for education policy makers.

In fact, a large body of researching provides suggestive evidence of a possible sensitive period for musical training in childhood with greater changes in auditory and motor regions of the brain, higher sensorimotor integration and better task performance achieved by those early musicians in comparison to musicians who began training later (Penhune, 2011).

The early music training influences positively the acquisition of absolute pitch and the structural and functional changes brain responses to musical expertise. However, these relative advantages of the professional musicians or amateur instrumentalists early trained should carefully be interpreted together with other variables of music-induced neuroplasticity and their interactions already referred on part 2.2.

In summary, it is a scientifically evidence that musical training shapes structural brain development and musicians’ brain constitutes a model of neuroplasticity. The early age of commencement, among other variables, has influences on the development of musical expertise and promotes brain plasticity across life span, facilitating future learning and a better adaption to ever changing environmental.

2.2.6. MUSIC, EMOTION AND REWARD

2.2.6.1. Emotion and cognition

Emotion is fundamental to learning and sustained human development (personality development, sociability and human well-being regulation). Emotion shapes and is shaped by cognitive process. “All learning has an emotional base”, has declared by the Greek philosopher Plato over 2,000 years ago. Scientific evidence that emotion is crucial to learning and the development of the human capabilities comes more recently with the emergence of the neuroscience applied to education (educational neuroscience). In particular, the affective brain network involved in learning is related with the emotional dimensions of learning such as interest, motivation and stress. The central role in emotional processes is played by the limbic system or the "brain's seat of emotion", which is highly connected with cortical areas involved with cognitive processing (Hinton et al, 2008).

For the purpose of this dissertation it should be convenient to understand the meaning of emotion and try to know something about the relation between emotion and cognition.

Recent advances of the cognitive neuroscience of emotions suggest that neural systems of emotion and cognition are interdependent implying that they could not be studied and understood separately. The neural structures involved in processing emotions involve the two brain regions: the orbitofrontal cortex and the amygdala. The amygdala plays a critical role in emotional learning and memory, through interactions with the hippocampus (Gazzaniga et al, 2002).

Emotion and cognition according the neurobiological evidence are regarded as two interrelate aspects of human mind and the emotional thought has strong implications in the processes of learning, memory, decision-making and creativity. Thoughts or direct stimulus (like listening to music or instrumental practice) can trigger emotions that have physiological effects on the brain and on the body and arouse feelings, which can in turn influence rational thought and creativity. Even more, neurobiology of emotions findings may point to a greater relevance for educators in understanding the nature of the relationship between emotion and cognition, in the sense that may be able to reinforce that virtuosi interconnection and the concept of better learning environments (Immordino-Yang and Damasio, 2011).

Additionally, according to Damasio "we probably cannot develop a comprehensive, integrated view of the human brain and mind, if we do not turn emotion into an important topic of investigation." (Damasio, 1998, p.84).

Damasio has also the scientific conviction that emotion and feeling should not be used like interchangeable terms. The term emotion should be rightfully used to define "a collection of responses triggered from parts of the brain to the body and from parts of the brain to other parts of the brain, using both neural and humoral routes. The end result of the collection of such responses is an emotional state, defined by changes within the body-proper, e.g., somatosensory cortices, neurotransmitter nuclei in the

brain stem". The term feeling should be used to describe the complex mental state that results from the emotional state (Damasio, 1998, p.84).
In summary, to understand the brain and its fundamental role on the learning science is crucial to further develop the investigation about cognitive neuroscience of emotion. Learning and playing music involves practically every cognitive function and positive emotions and pleasurable emotional states induced by music experience may facilitate learning and may have other transferable benefits.

2.2.6.2. Music and emotion

According to Isabelle Peretz "emotion is an integral part of music". Music is typically viewed as a cultural invention, but there is source of evidences regarding their biological foundations. There is a neurobiological link between music and the limbic system and "music emotions occur with immediacy, through automatic appraisal, and with involuntary changes in physiological and behavioural responses" (Peretz, 2006, p.23).
"Emotions are critical to our understanding of music…To understand the neural basis of music emotions is the central goal of neurosciences applied to music. This new field of research is the result of the advances of modern neuropsychology and neuroimaging techniques" (Kreutz and Lotze, 2007).
Different engagement with music produces different emotions. More active musical behaviors such as singing, playing musical instruments, or dancing may produce different kinds of emotional response, comparing with emotional effects of listening music. A large part of the studies about music and emotion is limited to the effects of emotions induced by music on passive listeners.
Music is considered the "language of emotions" by a large number of academics and researchers and the idea that music enhances emotions has been around for centuries. Musical experience, no doubts, has been played an important role in social and cultural ceremonies or events, and as a factor of social cohesion and a source of human individual pleasure and reward (Salimpor and Zatorre, 2013).
Besides the perspective of their intrinsic aesthetic value, musical experience in the perspective of the neurobiological framework could be characterized by the following aspects: (1) music evokes a broad range of emotions and feelings from joy and peace to

sadness and fear; (2) music-related affections are accompanied by physiological and behavioural changes (Habibi and Damasio, 2014, p. 93).

There is also evidence that musical engagement could change the state of the autonomic nervous system components, such as the heart and respiration rates, body temperature and galvanic skin reactions (homeostatic regulation) and activates brain structures correlated with music induced emotions and feelings, such as the “limbic system” (amygdala and the hippocampus) and the cortex (prefrontal and other cortices sub-areas involved with higher executive functions).

2.2.6.3. The pleasures and reward feelings of music

A significant part of the music-induced emotions and feelings can contribute not only to individual well-being, that comes from pleasurable or reward musical experiences, but also to a wide range of beneficial or utilitarian social experiences. The power of music to induce emotions and feelings, behind their eventual intrinsic “aesthetic” value, partially explains why music is so familiar from all cross-cultural societies and has been universally present in a considerable number of social events, such as religious ceremonies, weddings, and a variety of other celebrations (Habibi and Damasio, 2014).

Evidence shows that pleasure and reward feelings, among other affective responses, are evoked by music. A reward feeling can be defined as something that produces a hedonic sense of pleasure. Pleasure and reward are linked and both mobilize the activity of the limbic and paralimbic systems and respective amount of dopamine (neurotransmitter whose function is to regulate emotional responses) released when the brain responds to musical stimulus. The process of experiencing highly pleasurable music is translated in physiological responses, including the intensity of “chills”, and alterations in the muscular activity, heart and respiration rates (Blood and Zatorre, 2001; Zatorre and Salimpoor, 2013; Salimpoor and Zatorre, 2013; Habibi and Damasio, 2014).

Although sadness is generally seen as a negative emotional state, it should be noticed that sad music can be pleasant. This happens when sad music it is aesthetically pleasing and perceived as non-threatening, producing psychological benefits such as a mood regulation, and empathic feelings, such as an association with affective past events (Sachs et al, 2015).

Sadness is a complex bodily and neural state that affects the human homeostatic balance, reflecting the feelings of low energy, negative moods and social withdrawal.

Homeostasis refers to the process of maintaining internal conditions within a range that promotes optimal functioning wellbeing and survival (Habibi and Damasio, 2014).
The neurobiological framework, proposed by the authors, (Sachs, Damasio and Habibi) to understand when and how listening to sad music induces a pleasant response depends on whether a homeostatic imbalance is present at the outset (person's initial mood, negative or neutral) and whether music can successfully correct the imbalance. When aesthetically pleasing, sad music gives a pleasing response and restores the homeostatic balance of the listener.

2.2.6.4. Brain regions correlated with emotions induced by music

The recent neurobiological findings suggest that multiple regions of the brain are involved in the musical aesthetic and musical emotional processing; both of them involved brain's regions capable of generating reward feelings induced by musical-stimuli.
In general, emotional processing of music involves wide networks of central nervous systems activity, including limbic and sensory areas as well as those related with cognition and consciousness (Trainor et al, 2003, p. 314).
There is evidence, with the support of advanced neuroimaging images studies, that there are a correlation between emotional arousal and pleasurable experience responses to music (Salimpor and Zatorre, 2013, p. 66).
Emotions induced by music involve an increased activity of various neural regions of the autonomic nervous system. For instance, the hippocampal activity increases in response to music and this should not be surprising, as music has privileged access to memory (Salimpor and Zatorre, 2013, p. 68).
According to Koelsh "music is a universal feature of human societies, partly owing to its power to evoke strong emotions and influence moods". Functional neuroimaging studies on music and emotion show that music can modulate activity in brain structures that are known to be crucially involved in emotion, such as amygdala, nucleus accumbens, hypothalamus, hippocampus, insula, cingulate cortex and orbitofrontal cortex (Koelsh, 2014).
In music-evoked emotions, among all the mentioned brain regions, the most relevant roles are of the amygdala, the nucleus accumbens and the hippocampus. Amygdala has

a high network centrality within emotion networks and is particular sensitive to music that is perceived as pleasant or joyful (Koelsh, 2014).

2.2.6.5. The neuroscience of music and emotion and their implications to learning and education

Music–evoked emotions may be critical in relation to changes in brain structures that facilitate creativity, sociability and learning capabilities, and may also have strong implications for the development of music-based therapies for the treatment of neurological and psychiatric disorders.

The potential of music to evoke emotions makes music learning and training a valuable tool to provide an affective, motivated and creative framework in education to general learning and human development.

"The neuroscientific perspective of music and emotion needs interdisciplinary approaches, in which general models and theories of emotion, music theory, and brain research combine". This approach has implications to learning and education: "It can be stated from the outset, that emotions as a means, rather than an end, appear to play a major role in modulating human learning processes. Investigating the underlying neural structures and the functions of musical emotion might thus be an important step towards understanding human learning processes within and beyond the domain of music" (Kreutz and Lotze, p.145).

2.3. MUSICAL TRAINING AS A TOOL FOR LEARNING IMPROVEMENT

2.3.1. THE MUSICAL BRAIN FOR A BETTER LEARNING

In the last two decades, neuroscience researches supported on neuroimaging techniques noticed that musicians provided ideal models of brain plasticity. Scientific evidence points out for music-induced neuroplasticity, or in simple terms, the capacity of the brain to change in response to musical experience.

“The term ‘neuroplasticity’ refers to changes in the central nervous system as a result of experience and adaptation to environmental demands.” (Merrett and Wilson, 2011, p. 124)

Music training-induced neuroplasticity is a notable reference of learning among other acquisitive or adaptive human life experiences, and might influence strategic educational issues.

The brain that plays music is changed by it in response to the fact that processing music requires a complex combination of motor, auditory, visual, memory and emotional skills. Music training commencement in childhood, sensitive or optimal period to learning, may have the power to enhance the brain development and can be seen as a tool to promote brain plasticity across the life span.

Evidence shows that neural changes resulting from music training in childhood shape the adult brain and long-term neuroplasticity is retained, such as that one related with improved auditory and motor skills. For instance, music training induces functional and structural changes in the auditory system in a way that tones the brain for auditory fitness beyond music processing and through our lifetimes (Kraus & Chandrasekaran, 2010 and Skoe & Kraus, 2012).

Neuroscience investigations confirmed not just structural differences in musician’s brain in relation to nonmusicians, but also found differences inter-musicians in relation of increased neural activity associated to the musical instrument learned and trained. For example, pianists show increased neural activity in the auditory cortex in response to hearing piano notes. “The strength of neural activation to piano notes was found in correlation with the age at which piano training began and with the number of years of music training” (Kraus & Chandrasekaran, 2010, p.599).

Therefore, the learning and practicing of a musical instrument induces structural and functional brain plasticity associated with active enhancement of the auditory system, motor system, and sensorimotor integration, as well as with development of multimodal interactions across many regions of the brain. Long-term music training may also develop metaplasticity on auditory, tactile and motor processing tasks, which means that with the ongoing music instrumental training, the brain increases its potential for new short-term learning and plasticity to resolve advanced musical training experiences. Progress on instrumental music training depends also, among other factors, on a recognized reward value system and positive feedback (Herholz and Zatorre, 2012).

Overall, the musical brain, shaped by music training since childhood, is better prepared to learn across life span and some transfer benefits are susceptible to be found on cognitive and human development.

"Music provides a powerful tool to enhance learning because of its widespread effects on the brain and its ability to induce experience-dependent neuroplasticity. By harnessing the many and varied benefits of music making, it can create an enriched environment to stimulate the fundamental capacity of the brain to adapt to the ever-changing environment, thereby promoting our individual and social development." (Wilson, 2013, p.146)

2.3.2. MUSICAL TRAINING AND DEVELOPED MUSICAL SKILLS

Learning and music training initiating at an early age (preferentially up to 7 years old) has effects on structural and functional development brain, namely because playing a musical instrument requires a wide variety of skills, such as musical sigh-reading translated into bimanual motor activity synchronized with auditory feedback and highly sensorimotor skills (Schaulg et al., 2005; Hyde et al., 2009).

In other words, music training activates multiple brain networks during music reading, interpreting, listening and performance. Music training involves a large range of cognitive, emotional and social brain tasks, such as auditory perceptual processing, fine-motor skill learning, sensory-motor integration, highly developed sensory processing, visual and spatial processing, executive functions, emotional processing and social cognition (Wilson, 2013). The power of the "musical brain" includes the neural capacity to integrate multiple musical tasks and skills in the unified act of music instrumental practice.

The development of complex and versatile musical skills associated with music training, learning and practicing is provided by the notable adaptive feature of the human brain to change its structure and functions during learning and memory processing.

Learning and practicing a musical instrument involves changes in genes, synapses, neurons, and neural networks localized in some specific, but not exclusive, brain regions.

The perception of the relevance of musical training on changing the brains is well synthetized by Tierney and Kraus (2013, a):

> Musical training's ability to alter the structure of the brain is an impressive demonstration of that neural development is shaped by a complex interaction between genes and environment and can be, therefore, dramatically changed by experience through life (p.210).

Some research studies of neuroplasticity and education recognize the role of music training as an appropriate environment-experience to enhance brain plasticity, which is assumed to be an essential feature to prosecute a well successful educational/learning achievement (Thomas, 2012). It must be underlined that the nexus of music training and education is operated by neuroplasticity. Neuroplasticity is the brain science basis for school and lifelong learning. The recognized importance of neuroplasticity on educational matters is confirmed by a proliferation of papers on this subject and also in conferences organized by prestigious institutions, such as that one realized on 27-28 October 2010 in Vatican City about "Human Neuroplasticity and Education" (Published by The Pontifical Academy of Sciences, Vatican City, 2011, 250 pgs.). From that conference it is interesting to quote:

> In summary, bridges between brain science and education are numerous and quickly developing. Neuroplasticity is the key bridging process, and its molecular, neuronal and brain-wide mechanisms should be better investigated in the future. However, the state of scientific knowledge is already sufficient to conclude that investment in early education can have a profound impact on brain organization throughout life and therefore on health, economy, and social justice (Human Neuroplasticity and Education Statement, p.9).

Investing in early music education seems a correct educational option to improve children neuroplasticity and cognitive brain development, without disregarding the intrinsic aesthetic value of the music and their role on emotional learning and pro-social skills.

At this point of the dissertation, it is opportune to reflect a little more about the variables that influence the neuroplasticity induced by music instrumental learning and practicing, already superficially referred on part 2.2. Scientific evidence shows that there are structural (anatomical) and functional brain differences between musicians and nonmusicians. These differences are related with the core principles of brain plasticity and other moderating variables of music training-induced neuroplasticity.

The brain changes in response to the ten principles of experience-dependent neuroplasticity presented by Kleim & Jones (2008). These principles are applicable to neuroplasticity induced by music training, such as the principles of use it or lose it, use it and improved it, specificity, repetition matters, intensity matters, time matters, salience matters, age matters, transference and interference.

However, the core principles of neuroplasticity on general learning should be completed with a more specific paradigm of neuroplasticity induced by music training. This paradigm includes a set of moderating variables of music training-induced neuroplasticity and their interactions (see figure 9), and it is a result of a systematic review and interpretation of a large body of literature about music training, inherent neuroplasticity and influent variables (Merrett et al, 2013).

The set of variables that moderate the relationship between music training and neuroplasticity are divided by sub-groups, and includes the following: (i) age of commencing training; (ii) genetic predisposition, early auditory environment, personality and gender differences; (iii) absolute pitch ability; and (iv) instrument, type of training, practice and training variables, including metaplasticity associated with ongoing of music training.

Among overall factors that influence music training processing, early age of beginning of learning and training a musical instrument seems to exercise a profound impact on brain plasticity induced by music-experience and on their long-term effects on musical proficiency and nonmusical domains. Despite neuroplasticity can occur through the lifespan, the evidence suggest that there is a sensitive period to commence learning a musical instrument. The idea of a mark of up to seven years old as the ideal period to begin music instrumental education is supported by a large body of neuroscience research studies, of which the investigation of Schlaug and colleagues (1995) about the increased corpus callosum size in musicians who had begun musical training before the age of 7 was pioneer.

Some individual differences on music processing or performance are presumably linked to a favorable predisposition of genetic factors, such as musicality or the ability to dispose an absolute pitch. However, it should be noted that intensity and accumulated instrumental practice, quality of instruction and other musical experimental variables have also influent effects on music outcomes. So, music training outcomes is a mix result of the combination of nature factors with nurture factors.

In addition, type of musical instrument and type of music training also matters on music-induced neuroplasticity and brain changes. Neural motor adaptations to play piano or to play flute are clearly distinct, and we should not expect similar neuroplasticity and regional brain changes. The core principle of specificity tells us that "specific forms of neural plasticity and concomitant behavioural changes are dependent up specific kinds of experience" (Kleim & Jones, 2008, p.S229) or in more simply words "the nature of training dictates the nature of plasticity". Even more, the core principle of salience matters (Kleim & Jones, 2008, p.S231) means that "the training experience must be sufficiently rewarding to induce plasticity". This salience on training experiences relates with motivation and concentration, essential to promoting engagement in the task. An important distinction should be introduced to separate music "training" from music "practice". A learning strategy of "training" includes novel, challenging tasks with corrective feedback. By contrary, a learning strategy of "practice" limits the task action to repetition without external feedback (Wilson, 2013).

2.3.3. MUSICAL SKILLS TRANSFERS TO OTHER SKILLS

Transfer is a central concept in education. Most formal education aspires to transfer and usually the context of learning (school classrooms, educators, books, tests and curriculum programs with standardized tasks) differs markedly from the ultimate contexts of application (at home, in the society or in the job, with mix and complex tasks to be performed). Consequently, the final purpose of education is not achieved unless transfer occurs. Positive transfer occurs when learning in one context improves learning in another context. Transfers include near transfer (similar contexts and tasks) and far transfer (different contexts and tasks). Transfer is more likely to occur at near transfer level and/or when tasks share identical elements or cognitive processes (Perkins and Salomon, 1992).

Additionally, reflexive or low road transfer primarily reflects extended practice and it is relatively spontaneous by similarity of the processes, as for instance in the case of reading notation (music) and reading a text (language). By contrary, mindful or high road transfer is a result of a deliberate abstraction and intentional reflection to look for possible connections or common strategies on resolving a different task or kind of problem on a different context (Salomon and Perkins, 1989).

Overall, the complexity and enrichment of the brain's musical skills acquired with an early and consistent musical training experience may lead to transfer effects in nonmusical domains. Music training induces neuroplasticity and improves developing

cognitive functions and acquisition of nonmusical skills, like language, reading, abstract reasoning, mathematics and memory, during academic periods, and promotes learning and memory capacities on adult lifespan. (Hille and Schupp, 2013; Brandt et al., 2012; Tierney and Krauss, 2013; Brandt et al., 2012; Miendlarzewska and Trost, 2014)
Neural effects of musical emotions may also have implications on mediated affective responses to general experiences of learning, and the relevance of affective and social neuroscience to education can provide a new basis for innovation in the design of better learning environments (Kreutz and Lotze, 2007; Immordino-Yang and Damasio, 2011).

2.3.3.1. Overview of the musical skills possible transfers

In an extensive overview study "The power of music: Its impact on the intellectual, social and personal development of children and young people", Susan Hallam (2015), describes how learning and processing musical skills may near or far transfer to other non-musical skills. Active engagement with music may have positive influence on other non-musical activities (skills), namely: language development, literacy, measures of intelligence, general attainment, creativity, fine motor co-ordination, concentration, self-confidence, emotional sensitivity, social skills, team work, self-discipline, and relaxation.
Meanwhile, the study of Miendlarzewska and Trost (2014) offers an overall view of the variables influents on musical training and their correlative possible near and far transfer skills (See figure 10).

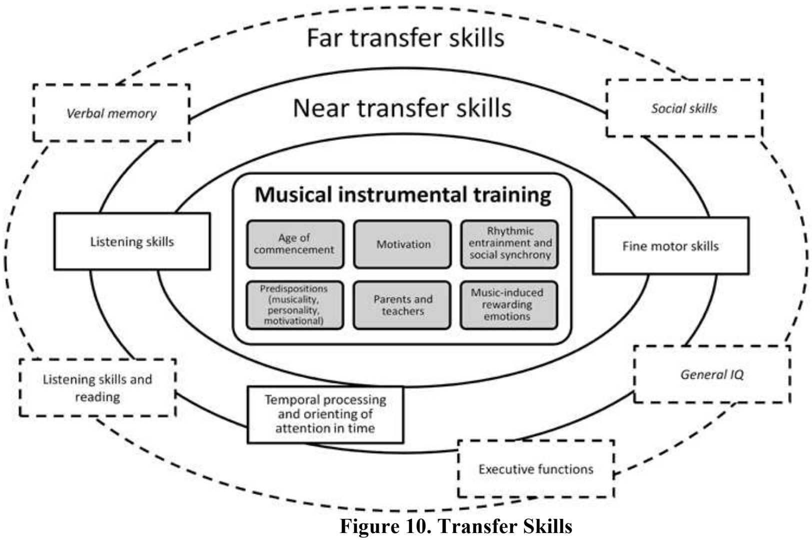

Figure 10. Transfer Skills

The study indicates as near transfer skills (in the domain of music): listening skills, fine motor skills and temporal processing and orienting of attention in time[1]. The far transfer skills considered (nonmusical domains) are: verbal memory, listening skills and reading, executive functions, general IQ and social skills.

2.3.3.2. Language and literacy skills

2.3.3.2.1. ***Music and development of language skills***

Language and music are among the most complex intellectual features of the human brain. Both are omnipresent in every different cultural society reflecting a distinctly superior intelligence communication form among primates. Humans are born with the potential to speak and make and enjoy music. The relation between language and music has been a long time topic of cognitive and biological research. In this part, we proposed to review some of the most relevant literature that hypotheses, suggests or concludes the benefits of musical training over language skills and literacy development.

As described by OECD report (2007), learning to read requires the mastery of a collection of complex skills, such as: (a) knowledge of morphology (letters to be used on writing); (b) comprehension of the orthographic symbols (spelling); (c) understanding of phonetics (mapping words to sounds); (d) knowledge of the semantic (the significance of the words); and (e) the dominance of syntactic rules (understanding the arrangement of words to identify the meaning of the message). All of these

[1] "*Temporal orienting of attention* is the ability to focus resources at a particular moment in time in order to optimize behavior and is associated with activation of left parietal and premotor cortex". (Coull, J.T., Nobre, A.C. 1998, Journal of Neuroscience 18, 7426-7435)

components of language require co-ordination and a working memory system (OECD, 2007, p.84).

The brain is biologically primed to acquire language. “There is indeed brain structures specialized for language: research has established the role played by the left inferior frontal gyrus (The Broca’s area) and the left posterior middle gyrus (The Wernicke’s area)” (OECD, 2007, p. 85). Although the human brain is biologically pre-prepared to language function the individual’s learning of a language is very sensitive to experience-dependences (educational factors including) and brain development stages. “The brain is optimally suited to acquire the sound prototypes of languages to which it is exposed in the first ten months from birth.” “There is an inverse relationship between age and the effectiveness of learning many aspects of language – in general, the younger the age of exposure, the more successful the language learning” (OECD, 2007, p.86).

The nature and features of the processing of learning a language has influence on the definition of educative policies designed to use early musical training experiences on improving language acquisition and developmental language skills.

“Although children make use of visual cues when learning language, audition is of primary importance for language acquisition” (Bailey and Snowling, 2002, p.135). The role of auditory processing is fundamental on children language acquisition. Basic auditory processing impairments may be associated with dyslexia and specific language impairment. Training auditory processing seems improving language skills, which both could be enhanced with music exposure (listening and/or practicing) since early children’s ages.

The auditory process is fundamental to develop the reading skills because it relates the consistency of neural response to the sound. The neural response consistency to sound is the ability to synchronize movement to a steady beat. “Response consistency – an objective measure of auditory processing that reflects neural synchrony – appears to be an important factor in the development of a successful reading” (Kraus and Anderson, 2013). Another study supports the strong link between consistent auditory responses (beating synchronization tasks) and improving the reading abilities. Musical training may have an important role in this link: “Musical training with a heavy emphasis on synchronization of movement to musical beats may improve auditory neural synchrony, potentially benefiting children with auditory-based language impairments characterized be excessively variable neural responses” (Tierney and Kraus, 2013 b, p.14981).

Neuroscience findings show that neuroplasticity induced by musical training leads to functional and structural changes in the auditory system that prime musicians for listening abilities and tones the brain for auditory fitness (Kraus and Chandrasekaran, 2010). The strength of neural activation in the auditory cortex in response to musical experience correlates with the age at which musical training began, and with the regular frequency and number of years of music training. Type of musical instrument, quality of the instruction and aptitude may also influence on the intensification of the neural stimulation.

Musical training improves auditory skills not exclusively to music domain, but transfer effects occur in other domains, such as speech, language, emotion and auditory processing. The same study explains that (Kraus and Chandrasekaran, 2010, p.600):

> Music training also involves a high working-memory load, grooming of selective attention skills and implicit learning of the acoustic and syntactic rules that bind musical sounds together. These cognitive skills are also crucial for speech processing. Thus, years of active engagement with the fine-grained acoustics of music and the concomitant development of "sound to meaning" connections may result in enhanced processing in the speech and language domains.

The benefits from long term music training practice in musicians versus non-musicians, could be observed also during childhood musical experiences and taken in account in other findings: "Children who are musically trained show stronger neural activation to pitch patterns of their native language, have a better vocabulary and a greater reading ability compared with children who did not receive music training" (Kraus and Chandrasekaran, 2010, p.603). These researching results have educational implications and the title of the research paper is very suggestive "Music training for the development of auditory skills". The author's conclusion leads to an educational direction: "Taking in consideration what we know about the positive effects of music training, it seems imperative that we afford all children an equal opportunity to improve their listening skills through music training."

A longitudinal study conducted, during 9 months, with 32 nonmusician Portuguese children, with 8 years old, confirmed, as predicted, that after musical training (with just 6 months learning and practice) children showed enhanced reading and pitch discrimination abilities in speech. The results of the study confirms the remarkably role of the brain plasticity induced by music training and their influence on neural development that improves musical abilities with positive transfer to reading and linguistic abilities (Moreno et al, 2009).

Research evidence also shows that adults who begins to receive formal music instruction in childhood leads to more robust auditory brainstem responses to sound and long-lasting positive effects on the adult brain. That is a clear example how the adult brain is shaped by musical training in childhood and sensible to long-term neuroplasticity (Skoe and Kraus, 2012).

Exploring the music-language relationship thematic, researchers Adam Tierney and Nina Krauss (2013 a) highlight the relevance of musical training on children linguistic development. Many evidences, some of them coming from the results of longitudinal studies, indicate that musical training can enhance language skills mainly reading ability. Transfer of learning from musical experience to language skills is possible because neural and cognitive necessary resources for reading acquisition overlap those related with learning music. Neural functions and abilities associated with reading ability, such as phonological awareness, speech-in-noise perception, rhythmic perception, auditory working memory, and sound pattern learning, have been shown be enhanced by musical training. In resume, researching results “may indicate that musical training can lead to increase neural synchrony through the auditory system, suggesting that music could be an effective way to boost reading skills in children” (Tierney & Krauss, 2013 a, p. 228).

In another study (Wong et al, 2007), researchers examined brainstems responses to linguistic pitch patterns in ten amateur musicians with at least six years of continuous instrumental training and finding a more robust and faithful encoding[2] responses

[2] Neuronal encoding of sound is the representation of auditory sensation and perception in the nervous system.

compared with ten nonmusicians; these results provide neurophysiologic explanations for musician's higher language-learning ability.

There is also a considerable literature supporting the positive correlation between musical training and early learning acquisition and later improvement in language development. In reality, musical training and expertise confer many language advantages to musicians, such as a more robust and faithful brainstem representation of pitch, a better ability to perceive speech in noisy environments or processing of prosody[3] and also to perceive and learn a second language (Brandt et al, 2012). These linguistic benefits of musical training are also observed on children that take music lessons, and are reflected in diverse ways, such as in reading development and phonological awareness, pre-linguistic communicative development or in a better ability to distinguish consonants. For the same authors, as they proposed, "If music cognition plays a strong role in early language acquisition, we would expect that musical training would correlate with improvements in language learning later in life" (Brandt et al, 2012, p. 10).

The influence of musical training on language processing has been object of a research paper by Sylvain Moreno (2009) entitled "Can Music Influence Language and Cognition?" The positive answer to this question is supported by a considerable literature review, but the author puts an interesting point of view about the "double direction" of the link between music and language: "Currently, most studies examine how music expertise or music training influence or modify language processing. However, it would be interesting to study how language expertise or training can modify music processing" (Moreno, 2009, p.340).

[3] Prosody term is related with tone or accent of a syllable and may reflect various features of the speaker (sarcasm, question, emphasis…) not reveal by the words.

The same author offers an interesting clinical perspective about the music-language link suggesting that musical training has an enormous potential as therapy in the cases of Speech and Language Impairment (SLI) or dyslexic children who have been found "to exhibit timing difficulties in the domains of language, music, perception and cognition, as well in motor control" (Moreno, 2009, p.341). Dyslexia is a specific learning disability that is neurobiological in origin and it is characterised by a phonological deficit, poor spelling and encoding abilities. Early identification of dyslexia is important as early target reading interventions are usually more efficient. Kraus and Slater (2015) defends that "a number of studies have demonstrated that deficient neural processing of speech can be strengthened by short-term training in children with language-based learning difficulties (e.g., dyslexia)" … and that "recent longitudinal assessments of existing music education programs provides support for the educational merits of musical training in fostering the development of critical language and learning skills" (p. 216).

In the view of the author of this dissertation, the role of musical training on developing effective educational interventions to help children with dyslexia to improve language-based reading and achieve linguistic and literacy abilities is a very important issue and specific area for academic research. However, it will be not developed in this dissertation given the pre-defined scope limitations of the study.

In summary, in face of all described literature and also in The Power of Music written by Susan Hallam (2015, p.31:37), early musical training in childhood develops aural perception processing systems and shapes the development of important neural auditory skills. The fine auditory specialization and the quality of aural encoding are related with the amount of musical training and the nature of the requirements of specific instruments. The earlier the exposure to musical learning and training and the greater the engagement in music practices the greater is the impact on developing neural auditory skills. Those who have had an early and consistent musical training showed a better discrimination between sounds and the auditory cortex is more developed. With the near and automatic transfer of all these skills, above mentioned, language acquisition and the development of linguistic abilities can be improved.

2.3.3.2.2. *Music training and development of literacy skills*

According to UNESCO, the conceptual meaning of "literacy' should expand from their classical view as "a simple process of acquiring basic cognitive skills, to using these skills in a ways to contribute to socio-economic development, to developing the capacity for social awareness and critical reflection as a basis for personal and social change" (Education for All Global Monitoring Report, 2006, p. 147).

This enlarged conceptualization of "literacy" highlights their relevancy on children cognitive development and on educational strategic goals. Literacy could be simply consider as "a set of tangible skills – particularly the cognitive skills of reading and writing – that are independent of the context in which they are acquired and the background of the person who acquires them" (EFA, 2006, p. 149). Acquired linguistic abilities are not the same as to acquire literacy skills. The emphasis on the essence of literacy is associated with human rational ability to use efficiently the reading, writing and oral skills in different human contexts and external environments, in ways to positively contribute to individual and societal development. This conceptual idea of literacy is quite the same as that one expressed by UNICEF (EFA, 2006, p.158):

> Functional literacy is the ability to use reading, writing and numeracy skills for effective functioning and development of the individual and the community. Literacy is according to the UNESCO definition ["A person is literate who can, with understanding, both read and write a short statement on his or her everyday life"].

Even more, literacy can be viewed as an active and broad-based learning process, rather than as just a product of an educational intervention limited on time and duration. This idea is focused on fundamental learning experiences during lifespan: "learning on/with human everyday practices". Paulo Freire is perhaps the most famous educator to support the idea of integrating the active learning "learning praxis" within the social-cultural contexts to transform and build a better social world. Freire's ideas have been used on the conception of El Sistema as a pedagogical tool to promote cognitive development and educational, parental and social integration of all children, never mind their social-economical origin, through engagement in music instruction and practice in the orchestra, chamber music or vocal group.

For the purpose of this dissertation, it is convenient to define the concept and the term "literacy" as "the ability to read and understand a simple text, and to use and transmit written information of everyday life" (France adaptation, 2005, cited by EFA, 2006, p.148).

According to the adopted definition of literacy the role of musical training is not just facilitating the acquisition of language skills, but also to contribute to the development of “reading with comprehension” skills (or literacy skills). So, the relation of musical ability with literacy ability is much more complex than the one that simply relates music ability with language ability.

Musical skills correlate significantly with phonological awareness which is an important precursor to early reading. Evidence shows that children musical instruction supports the development of pitch and rhythmic skills, which shapes the auditory system to the efficient development of reading abilities. Reading musical notation plays an important role on promoting reading abilities as well on achieving some mathematical abilities. There is also evidence for an association between musical training, music abilities and reading skills which is typically explained by near transfer theories (Hallam, 2015).

Additionally, the contribution of musical training to enhance the executive functions and other intellectual abilities seems fundamental to the development not just of the reading abilities but also to reading with comprehension. On a research study (Sesma et al, 2009) the authors looking for the contribution of executive skills (working memory and planning), to reading comprehension in 60 children with the ages 9-15 years. They find a significant contribution of the executive functions to reading comprehension, among others contributors, such as attention, decoding skills, fluency and vocabulary. The authors explained (Sesma et al, 2009, p.8):

> “Reading comprehension is inherently more complex than single word reading, with demands that go beyond basic phonological decoding and word identification and include higher order cognitive processing of meaning conveyed through sentences and paragraphs. As such, it is not surprising that executive skills are better predictors of reading comprehension than of single word reading. Working memory in particular has long been thought to play a role in reading comprehension because of the need to hold already-text in short-term memory while attempting to extract meaning from individual sentences and paragraphs.”

The results of this study emphasis the importance of musical training to contribute to the children development of musical abilities at the same time with the development of executive functions as a way to improve reading comprehension. The impact of music instruction on intellectual development and executive functions would be analysis on a later part of this dissertation.

The positive influence of music instruction on literacy development has been found on a longitudinal study involving 42 children aged 6-9 years from low-socioeconomic status in Los Angeles (Slater et al, 2014). The study concludes that after one year of music training, children retained their aged-normed level of reading performance, whereas a matched control group's integrating low-income children with no music instruction reveals a modest decline in scholar performance in line with general tendency observed for disadvantaged social groups. The results of the study suggest that (Slater et al, 2014, p.7):

> It is possible that participation in an engaging music program may influence the development of reading skills by increasing a child's overall motivation to learn and that observed benefits are therefore not the result of playing music, per se. However, increasing student motivation is not a trivial accomplishment; one of the unique characteristics of music is its ability to engage an individual on many levels, socially, emotionally, intellectually and creativity, promoting other aspects of development such as self-confidence and discipline and fostering social cohesion.

Looking for the design of educational strategies to promote literacy since early ages on children in at-risk communities, engagement with music programs can be a powerful instrument to surpass the many obstacles of the non-literacy tendency observed in these disadvantaged groups, while providing benefits for individuals and communities in terms of artistic development, intellectual development and personal and social integration.

Other researching work (Degé et al, 2015) aimed to studying the associations between music abilities and precursors of reading in preschool children, conclude that music perception and music production influence positively the precursors of reading, such as working memory, phonological awareness and rapid retrieval from long-term memory, all of them valuable to promote language abilities and a predictable better literacy development.

The results of a longitudinal study (Cain et al, 2004) that addresses the relations between working memory capacity and reading comprehension skills in children age, 8, 9, and 11 years, leads to a conclusion (and confirm other investigations) that "working memory should be regarded as one of several factors that can influence comprehension ability and comprehension development." Thus, educational programs, including music education, should take in consideration the relevance of working memory, among other components of reading comprehension, while promoting children's literacy development.

Meanwhile, Corrigall and Trainor (2011) found a strong association between length of music training and reading comprehension which probably involves a functional mediation of word decoding (process of translating a written word into a sound). Those researchers admit the advantages of music lessons on promoting literacy achievement by the essential explanation that "music training teaches children self-discipline and attentional skills that help them concentrate for long periods of time." … "Perhaps music lessons help children to become more efficient learners who are able to focus better and concentrate for longer periods of time, which ultimately leads to important educational benefits" (Corrigall and Trainor, 2011, p.153).

In summary, the selected literature review demonstrates that children with early and consistent engagement with musical training revealing significant improvements in neural auditory skills (Kraus studies and others) and develops specific musical abilities, which are subject to near or far transfer to enhanced linguistic abilities and reading with comprehension (literacy ability). This is in line with Susan Hallam conclusions in The Power of Music (2015, p.45): "While the precise nature of the relationships between musical training and reading skills are currently unclear there is sufficient accruing evidence that musical training which supports the development of pitch and rhythmic skills supports the development of fluent reading leading to enhanced comprehension".

2.3.3.3. Mathematics and spatial abilities

Learning mathematics is a process that necessarily involves the genetics tendencies (nature) combined with experience – dependent factors and environments (nurture). The neurological processing of mathematics in the brain, which involves the central role of parietal cortex, is dissociable from other cognitive domains, as well as the abilities in the domain of mathematics can be dissociated from one another (OECD, Numeracy and the Brain, 2007).

The first of these processing mathematics principles supports the notion of a multiplicity of partially distinct intelligences ("Frames of Mind" Gardner, 1983). In reality, exceptional ability or deficit in mathematics does not necessary imply talents or deficits in other cognitive domains. The second principle means that ability in a certain subdomain of mathematics is not necessarily indicative of a global mathematic ability.

So, the validity of criteria used for performance of evaluation in mathematics (or in a subdomain of mathematics) should be carefully used or interpreted.

The OECD publication (2007) highlights that the neurological processing of mathematics involves a highly disperse network of brain structures and "even an act as simple as multiplying two digits requires a collaboration of millions of neurons distributed in main brain areas." (OECD, Numeracy and the Brain, p.101) Furthermore, it seems that there is some similar neurological processing involving the parietal circuit critical for numeracy and for the representation of space. Probably these two functions are intertwined, and there may be a biological predisposition to associate number with space, which could have implications on instructional mathematics methods (OECD, 2007, p.102).

2.3.3.3.1. ***Music and mathematics: associations***

There has been an empirical idea that acquiring musical skills improves mathematics reasoning. This can be explained providing some examples, such as, when playing an instrument, musicians are constantly required to adopt quasi-mathematical processes to translate rhythmic and other musical notations into organized sound. More controversial, it is somewhat popular that just listening music (or some specific pieces of music/composers) improves the spatial reasoning and other mathematics skills. The connection between music and mathematics depends on various conditions: kind of musical involvement (e.g. active instruction or passive listening), duration, intensity, starting age and quality of the musical experience-dependence, as well as subdomain of mathematics subject to the proposed study correlation.

The research exploring the relationship between active musical participation or "music instruction" and mathematics abilities seems to have more consistent results than those that simply explore the relationship between passive music listening and spatial reasoning, which could be considered one subdomain of mathematics and a possible predictor of mathematics performance.

2.3.3.3.2. ***Listening music and the Mozart effect myth***

In 1993, Rauscher, Shaw, and Ky (journal Nature) revealed the surprising research about the following: after listening to Mozart's sonata for two pianos (K448) for 10 minutes, a group of college students showed better spatial reasoning skills than other two non-listening music groups. Spatial ability is the capacity to understand and remember the spatial relations among objects. Spatial ability is important in many fields of study like, engineering, architecture, professional designers, meteorology, and astronomy among others.

The results of the 1993 study "Music and spatial task performance" received widespread attention from media and soon the investigation has been better known as "The Mozart effect" a term coined by the Los Angeles Times and some time later edited as "Mozart makes you smarter". Academic literature published after 1993 concludes that "Mozart effect" varies on their results between individuals and spatial tasks chosen, and the positive results (when reported) are not specific to Mozart's compositions: the spatial skills enhancement is small and with short term duration and general intelligence were not affected (Jenkins, 2001).

2.3.3.3.3. ***Music listening is not the same as music instruction***

In reality, Rauscher (herself) and Hinton (2006) explained, in another study, the limitations of "The Mozart effect" by emphasizing that music listening is not music instruction. Research works have found, after the famous 1993 article, which young children provided with instrumental instruction scored higher on tasks measuring spatial-temporal or other similar cognitive abilities. Also the effects of music instruction have been found to persist more time after the instruction was terminated (Rauscher and Hinton, 2006).

Better results come from music instruction or music training than from passive listening music. Improving the spatial reasoning ability is not a surprise because learning to play a musical instrument implies reading musical scores and involves the development and coordination of specific perceptual, cognitive and motor skills which are likely to transfer positively to other cognitive domains (Rauscher and Hinton, 2006).

Perhaps one of the most relevant papers in this field was published by Schellenberg (2001), who claims that exposure to music produces benefits in nonmusical domains, but, first of all, we should make an important distinction between the short-term consequences of music listening by opposition to the long-term consequences of formal training music. The author, after having revised other studies, considers that there is suggestive evidence that music lessons have positive nonmusical side effects and that positive association can be based on neurological findings. Musical training can alters patterns of cortical organization especially for children who begin music lessons at an early age when brain is relatively plastic. The same author highlights that the short-term effect that comes from listening music is small and unreliable, and eventually that effect can be explained by the differences in the listener's mood or levels of cognitive arousal. By contraire, the effect of music lessons has more indications to be transferable to other nonmusical skills, such as linguistic, mathematical and spatial domains (Schellenberg, 2001).

In a similar way, Hallam describes that the development of spatial reasoning abilities seems to have a favorable correlation with professional musical activity. However, the same academic admits that this may be a result of the fact that musicians already have strong spatial and temporal skills, with more salience among those that received early instruction and better quality of musical input. In particular, rhythm instruction has the strongest impact on a range of mathematical related tasks, and the quality of the musical input is crucial in any transfer of skills. Taking all the research in consideration, the same author concludes that the evidence suggests that active engagement in musical activities enhances a range of spatial skills, but further investigation is necessary to explain better this correlation and the nature of the specific musical activities involved (Hallam, 2015, p. 53,54).

2.3.3.3.4. ***Music and mathematics: historical connections***

Historical connections between mathematics and music persist since the Greek antiquity until our Modern times have been well documented and exposed by some academics (Shah, 2010). In a notable academic study "An Exploration of the Relationship between Mathematics and Music" the author highlights the millennia historical connections between music processing and mathematical reason and focus on subjects like the mathematics of music, the religious symbolism and numbers in Bach's music or the mathematics as art. At the time of Pythagoras, music is indeed very mathematical and mathematics is inherent to many ideas in music theory. He was the first to develop the theory of intervals. Greek mathematics education was comprised in four sections: number theory, geometry, music and astronomy (Shah, 2010, p.12). Mathematics explains, for example, how strings vibrate at certain frequencies, and how the instruments shapes give that specific timbre (tone quality).

There were some examples relating mathematics and music theory, and some of them have a long historical past. Reading musical notes is related with counting lines and spaces to play the right notes. Also reading rhythm is always kept up with counting steady beats and implies how to learn the technical elements in the score. The rhythms notes can be very complex with some modern erudite compositions and we can resume that the more music we learn the more mathematics we need. Some famous erudite music composers, like Johann Sebastian Bach, seems to have used numerical relationships between sequences of notes to communicate their Bible religious ideas on their compositions. Sometime later, Olivier Messiaen uses his unique musical techniques based on mathematical structures to express religious ideas of strong and intense faith in Roman Catholicism. (Shah, 2010, p.73)

2.3.3.3.5. ***Mathematics and Music: the Musician approach***

The power of music to propagate some musical ideas and create aesthetically pleasant emotions is derived in a great part from the use of mathematics as a tool to compose beautiful works through a long period of history. We really could say that music without any mathematics is difficult to have a conception of the compositions, to read musical notation, to interpret a composition, to do the analysis or simply to enjoy the music pieces or complete works. Mathematical reasoning involved in musical compositions is expressed in some particular forms – time, rhythm, and pitch, to sub-divide beats, or fractional differentiation of rhythmical notes (whole notes, half notes, quarter notes, eight notes, etc.), and of musical notes (half tone, whole tone, 5th perfect, etc.)

Music itself is indeed very mathematical and mathematics is inherent to many basic ideas in musical sounds. Mathematics helps us to describe the conception and structural configuration of a composition. Mathematics explains how strings vibrate at certain frequencies, how the instruments shapes give that specific timbre (tone quality), and so on.

Reading music everyday has a huge impact in a day of a musician’s life. The impact towards a music beginner might be slightly bigger than in the advanced musicians.

Trough notation (See figure 11) it is possible to represent musical sounds and their proprieties, coding music to be performed by someone and acting as an aid for the memorization of music to play later in a performance.

Figure 11. Musical example 1

Counting lines and spaces everyday of staves in different scores to ensure the young musician plays the right notes is a time consuming (a bit stressful and not 100% infallible).
The advanced musician may not need so much strain but once in a while there is that counting just to make sure. The above example is mere basic counting, and there besides reading the notes there is also the fingering notation (each note should have a fixed finger position). For an advanced musician sight-reading becomes more like reading a map and fingering becomes more instinctive.

Figure 12. Musical example 2

Reading the rhythm is always kept up with counting steady beats.

To read the rhythm a young musician needs the following elements in the score: a time signature and bars.

Unlike what happens to reading notes, rhythms can be infinitely complex and the complexity can increase if the advanced musician is willing to take the challenge, as it can happen with some contemporary (almost incomprehensible) compositions.

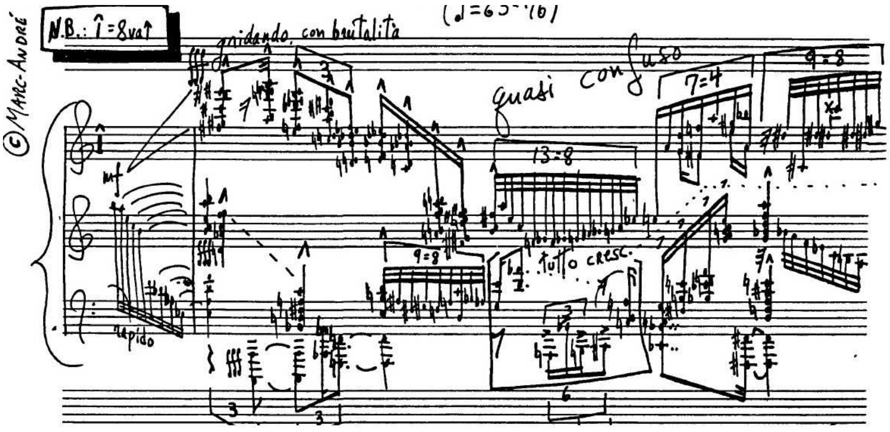

Figure 13. Musical example 3

The density and complexity of the suggested rhythmic pattern shows that there are some limits on the use of mathematics to create understandable and aesthetical value music.

2.3.3.3.6. ***Learning music and mathematics: some similarities***

Music can be pivotal for effective mathematics learning for children. Music can provide a favorable context to teaching/learning mathematics by fostering motivation, emotional intelligence and interest. Understanding basic mathematics concepts and principles, involves a comprehension of patterns, relationships, proportions and fractions, which is somewhat present on musical understanding in terms such as rhythm, pitch, duration, dynamics, tempo, texture, all of them translate in notation (Hilton, 2015).

By integrating the music instruction on early childhood school phases it is expectable to have a beneficial effect on children mathematics achievement. Early music instruction curricula should integrate a theoretical and a practical component, in a way that Youngers music students would gradually dominated the musical terms, read a notation of a piece of music and play an instrument.

The same educational strategic idea to link the early learning math concepts with the music training skills has been professed by some researchers such as Gardiner (2000) who believes in a process of learning math and other subjects through music training abilities or by a “mental stretching”. “What I am calling “mental stretching” focuses attention on the role of representation and change in representation in learning.” (Gardiner, 2000, p.74)

The impact of music on mathematics achievement has also been support by some music programs, such as “Kindermusik program” designated by ABC Music & Me. The program focus on the link between mats curriculum (USA), based on the National Council of Teachers of Mathematics (NCTM), and their connection with appropriated music concepts or terms, as shown in the following table.

Table 3. Focal point and Music

Focal Point	***How It Relates to Music***
Number and Operations: Developing an understanding of whole numbers, including concepts of correspondence, counting, cardinality, and comparison	Counting beats (“how many” in a rhythmic pattern) Comparing beats (“more,” “less”)
Geometry: Identifying shapes and describing spatial relationships	Notation (notes are “higher” or “lower” on the staff) Organizing patterns of sounds
Measurement: Identifying measurable attributes and comparing objects by using these attributes	Tonality (“higher” or “lower”) Pace (“faster” or “slower” rhythms)

(NCTM, 2008)

Note: Focal point means the curriculum focal point for Prekindergarten provide by the National Council of Teachers of Mathematics (NCTM) in the year 2008 (USA).

Source: The Impact of Music on Mathematics Achievement: A Research Summary In Support of Kindermusick’s ABC Music & Me.

2.3.3.3.7. ***Music and mathematics: the neuroscientific approach***

Focusing on neurological or cognitive aspects, most of the scientific studies exploring the relationships between musical practice and mathematics have had positive results but some of them are presenting mix results. For example, a longitudinal study using a national data based in United States of America with more than 25,000 students in

American secondary schools for 10 years, found positive effects on mathematical performance for those engaged with music: “Students who report consistent high levels of involvement in instrumental music during the middle and high school years show significantly levels of proficiency by grade 12” (Catterall et al., 1999). The same study also concludes that students with low socio-economic status and high involvement in music do better than the average students at attaining higher levels of mathematics proficiency.

The answers were more positive about the core question “whether instruction in music is associated with higher core abilities in the numerical and spatial domains” and they were provided in another author/investigation (Spelke, 2008). Taking in methodological account that, according to cognitive neuroscience findings, the mathematical ability is not confined to one system in the brain, the author highlights (p.47): “… our experiments provide evidence for an association between music and geometry only when training in music is intensive and prolonged” and that “… findings provide no evidence that short-term, low-intensity training in music enhances abilities at the foundations of mathematics.”

In the same way, Santos-Luiz (2007) advocates learning and musical practice as a means to improve mathematical skills, including spatial-temporal reasoning. In reality, the author supports that music practice is connected to several different areas of mathematics: arithmetic, geometry and trigonometry and that music ability is a distinct intelligence form of Gardner’s theory of multiple intelligences (1983). He thinks that facing some of the most relevant research findings, and under given circumstances, it is reasonable to infer that musical involvement may improve reasoning related with certain mathematical concepts and spatial-temporal reasoning, and even can promote academic mathematical achievement.

Some neurobiological researchers, namely Schmisthorst and Holland (2004), show evidence of the correlation between formal musical training and mathematics performance. The authors based their investigation on neuroimaging (fMRI) technics to observe the effects of mathematical tasks on adults with musical training since early childhood (musicians) and other adults without musical training (nonmusicians). Significant brain differences were found also in the neural correlates of math processing between musicians and non-musicians, despite the small sample size used. After the results of this neuroimaging investigation, the authors hypothesized that correlation between musical training and math proficiency may be associated with improved working memory performance and an increased abstract representation of numerical quantities (Schmithorst et al., 2004).

In summary, confronting the literature review it seems in general that musical training, much more than music listening, may be associated with positive transfer to some aspects of mathematics abilities but not in an absolute way. When speaking about more consistent correlation between music and mathematics, short or long duration of the positive transfer to enhance specific mathematics abilities (or mathematics subdomains), depends namely on the beginning age, length, intensity and quality of musical instruction (type of music instrument is not indifferent also) and correlated neurological activity or brain structural alteration derived from learning and practice music.

Overall, the evidence suggests that engagement in musical activities enhances a range of spatial skills, but this must be supported by extensive musical training instead of just music listening during short periods of time (Mozart effect is a myth). Improving of spatial abilities may predict a better mathematical performance. Active engagement with music may be also be able to improve other subdomains of mathematics, but the nature of this relationship depends on the kinds of musical training needed to realize the effect, the length of time required and the quality of the musical program. Music learning and mathematics learning have some thinking affinities and neuroscience evidence points to somewhat common neural processing and possible cognitive transfer from music learning to mathematical skills. Integrating musical training curriculum since early childhood school phases should improve children's mathematical development. Musical training should include learning notation that symbolized musical proprieties (sound) in a similar way that mathematical proprieties are symbolized in mathematical language.

2.3.3.4. Intellectual Development and Executive Functions

2.3.3.4.1. ***Music training and intellectual development***

There has been some temptation to invoke some causal relationship between musical engagement and intellectual development or intelligence of the children. The "Mozart Effect" is an example of an inconsistent extrapolation of the effects of the relationship between music listening and intellectual development in the sense that listening "Mozart makes you smarter" as no scientific support and rather it is a myth. Passive listening music (Mozart sonata or eventually other piece of music classic) just improves temporarily spatial-temporal performance, a consequence of the music effects on reward and positive mood.

In reality, musical engagement may have an impact on intellectual development, but this depends, among other factors, on the nature of musical activity (passive listening, instrumental training, choral singing, chamber music, composition…), which generates different neuronal plasticity activity, musical skills acquisition and respectively effects (or not) on nonmusical cognitive domains.

The idea that music instrumental lessons for children have collateral benefits that extend to nonmusical areas of cognition, such as enhancing the intelligence, has been supported by the extraordinary experience-dependence that music training provides as explained by Schellenberg (2004, p.511-514):

> Music lessons involve long periods of focused attention, daily practice, reading musical notation, memorization of extended musical passages, learning about a variety of music structures (e.g. intervals, scales, chords, chords progression), and progressive mastery of technical (i.e., fine-motor) skills and the conventions governing the expression of emotions in performance. This combination of experiences could have a positive impact on cognition, particularly during childhood years, when brain development is highly plastic and sensitive to environmental influence.

The perspective that early music instruction has a positive impact on cognitive functions and intellectual development may be supported by neurophysiological theories and by an increased number of brain studies involving neuron images. Studies have shown that early music instruction influences the brain, perception and cognition.

Early and extensive practice on a musical instrument can induce cerebral cortical reorganization, increases synaptic strength and produces functional and permanent changes associated with the acquisition of musical abilities and expertise. Spatial, sensorial-motor, sight-reading, fine tuning, working memory and music perception tasks related with music trained induces neuroplasticity and prepares the brain to positive transfer to non-musical domains and other cognitive abilities.

Considering childhood period (5 to 12 years old), music education, music training or music lessons (all having in common, at least, formal instrumental lessons and regular practice), neuroscience research findings suggest positive associations or correlations between musical activity and human intelligence performance. For instance, a (particular) certain study concludes long term positive associations between children (6 to 11 years old) with music lessons and their IQ (Intelligence Quotient), even when socio-economic status, parent's education or others confounding variables were taken in consideration (Schellenberg, 2006).

Studying and playing a musical instrument during one or more years develops a substantial neurological activity and induces brain's plasticity in a way substantially different in relation to the listening of the music for some minutes. Research results from Hille and Schupp (2013) show some evidences that the impact of learning and practice a musical instrument has much more positive effects on intelligence and general cognitive abilities than other tested participants (students-boys with 8-9 years old) involved in other musical activities (but not instrumental players).

So, the up referred study confirms the Schellenberg (2005) conclusion that music lessons, unlike music listening, are associated with small but general and long-lasting intellectual benefits. Music (instrumental) lessons, as extra-curricular activities, might give special benefits for children, as long as they enjoy music. Multiple skills are trained and abstract reasoning is improved, all of that resulting in a more proficiency of the general learning.

More recently the same author (Schellenberg, 2011) investigates more deeply the nature of the association between music lessons and intelligence, particularly if: (i) such association is general or subset to specific intelligence abilities; (ii) there is (or not) a cause effect relationship between music lessons and intelligence improvement and (iii) that association is mediated by executive function.

Testing musically trained and untrained children between 9 to 12 years old (on a total of 106 participants, 54 boys and 52 girls) on a set of IQ measures, the study confirms the reasonability hypothesis to establish a causal relation between music lessons and a relative higher intelligence performance given the fact that there is a relevant experience-dependence neuroplasticity induced by musical training, which is assumed to cause changes in brain structure and function. But the author, despite the strong position of the nurture factor, alerts to the possible existence of an influent nature factor (genetics differences) to partial explain the difference in IQ between musically trained and untrained children. Furthermore, other variables like personality differences or genre singularities, socio-economic status, parents' influences and musical teaching environment, quality, frequency or programs may all have influence on the complex association between music lessons and intelligence.

The results and the discussion of the study lead to some relevant conclusions (p.297):

> In sum, the association between music lessons and intelligence is undoubtedly complex. It is important to recognize roles of nature and nurture in the association, to considering individual differences in personality as well as intelligence, and to broaden the focus to explain what appears to be a special link between music lessons and academic achievement. Careful consideration of what makes children with music lessons particularly good students could help to resolve outstanding issues about associations between music lessons and intelligence.

Another author (Costa-Giomi, 2004, p.26) expresses the relevant plurality of variables relative to the same association as such:

> In other words, the superior intellectual performance of students who choose, persist, and succeed in learning music may be the result of other educational opportunities in which they participate, or the characteristics of their parents and home environment, or certain personality traits that contribute to their intellectual development rather than the effects of music instruction per se.

So, this kind of association should be carefully interpreted given the complexity of the issues, the multiplicity of variables to control and the fact there are no universal and definitive conceptions of intelligence and intellectual development (Hunt and Jaeggi, 2013). Gardner's Theory of Multiple Intelligences exemplifies the complexity of the human intelligence understanding and the difficulty to measure multiple intellectual abilities. The theory of multiple intelligences was first developed by psychologist Howard Gardner in 1983 and revised in 1999. The eight identified intelligences included linguistic intelligence, logical-mathematical intelligence, spatial intelligence, musical intelligence, bodily-kinesthetic intelligence, interpersonal intelligence, intrapersonal intelligence and naturalistic intelligence (the latest intelligence was introduced in the 1999's revision). Musical intelligence includes sensitivity to pitch, rhythm, and timbre and the ability to compose, singing, playing an instrument or appreciate music.

Considering other theories of "intelligence", seems plausible that music training is associated with some improvement of the skills related with emotional intelligence, because learning and performing music requires perceiving, understanding, using with rationality and managing emotions in social contexts. Salovey and Mayer first developed the concept emotional intelligence in 1990. "Emotional intelligence refers to the ability to recognize the meanings of emotions and their relationships, and how to reason and problem-solve based on emotions. Emotional intelligence is involved in the capacity to perceive emotions, assimilate emotion-related feelings, understand the information of those emotions, and manage them." (Mayer et al., 2000, p.267).

This researching topic – the music instrumental learning and performance and their role on develop emotional intelligence - seems not sufficiently explored, despite a study suggests the positive association between classic music piano performance and emotional intelligence (Resnicow et al., 2004). Further studies, preferentially longitudinal one, should be applied to younger adults with many various years of practicing a musical instrument (e.g. piano, violin, flute…) compared with adults of same age with no relevant music practice. Emotional development of the children, or the acquisition of emotional thought, has a critical role in education, because neurobiological evidence shows that cognition and emotion must be seen as two interrelated aspects of human functioning. "Simply having the knowledge does not imply that a student will able to use it advantageously outside of school." (Immodino-Yang and Damasio, 2011, p.128). "We feel, therefore we learn", express the core idea how much emotional intelligence could be important or essential during our school and lifespan of learning.

In summary, it seems that there are sufficient findings to conclude that early and active musical engagement, such as music learning and training a musical instrument, has a positive and long-duration impact on intellectual development (Schellenberg and others, 2005). However, the complexity of the relationship between music education and intelligence, the individual specific combination of nature and nurture cognitive and emotional contextual variables (including quality of music education and type of musical activity), and the multiplicity of possible intelligences and their different subsets of measures of intelligence, requires special care in the interpretation of that relationship and generalized conclusions about intelligence induced by experience-dependence music training.

2.3.3.4.2. ***Music Training and Executive Brain Functions***

In the human cognitive development, executive functions are higher cognitive functions that encompass a broad range of neuropsychological processes that allow us to generate concepts, to reason, to plan, to solve problems, to control our behavior, and to decide how to interact with the world.

Executive brain functions involve the coordination of many different parts of the brain, with the prefrontal cortex playing the central role, in order to process and coordinate difficult or complex multi-tasks, make decisions and plan for daily tasks or future challenges. All of that requires the developing of executive function skills that facilitates what we would designate by “intelligent” behavior.

Among the several types of executive function skills, working memory, inhibitory control and cognitive or mental flexibility are some of the most important of the integrate-development of a competent executive function. Working memory is the capacity to hold and manipulate information in our brains over short periods of time, enabling us to manage our everyday multi-tasks or goals. Inhibitory control is the skill used to filter our thoughts and impulses to be able to resist to temptations, distractions, and habits and to pause and think before acting. Cognitive or mental flexibility is the capacity to adjust to novelty or changing task demands, priorities, or perspectives. (Definitions based on Center on the Developing Child, Harvard University, Working Paper 11, 2011)

The prefrontal cortex, which is responsible for higher-order thinking and coordination of executive function skills, is still maturating in the adolescent brain, and the maturation process is not completed until young adult, perhaps as late as 30 years old. The way in which the prefrontal cortex is developed during adolescence may affect the emotional regulation. The still under-developed prefrontal cortex among teenagers may play a role in the higher incidence of unstable behaviour during adolescence (OECD, 2007, p. 46, 47).

Neuroscience and Education experts refer that “the increasingly competence executive functions of childhood and adolescence enable children to plan and act in a way that makes them good students, classroom citizens, and friends” (Center on the Developing Child, Harvard University, Working Paper 11, 2011, p.3).

2.3.3.4.3. ***How music training relates with executive functions***

Music training information is processed by multiple brain systems, involving different brain regions and functions. As a complex task, music processing consists on a range of highly developed and well-integrated sensory, perceptual and motor skills, which requires the prime use of executive functions, self-regulation and high attention levels. Executive functions and attention on music processing are strictly necessary for "auditory and spatial working memory and imagery, selective and sustained attention, planning, creativity, problem solving and decision making" (Wilson, 2013, p.142).

Correlative studies have explored the relationships between music practices and enhanced executive functions, and important findings leads to positive correlation with some of those functions, although still subjected to further research. Some elements of executive functioning are clearly enhanced by musical training, such as working memory which is vital to music expertise or music performance (Killough et al, 2015; Nutley et al, 2014).

With or without music training what is clear is that executive functions are imperative for learning and they have impact on academic attainment at all levels (Best et al, 2011). Evidence suggests that the healthy development of executive function skills can be supported with specialized practice and training that improve the neuroplasticity of the childhood and adolescent brain development. In this sense, music training may be seen as a tool to accelerate or enhance the executive functions skills and subsequent improvement on learning capacity and academic results.

In one longitudinal study covering children and adolescents aged between six and 25 years old, participating in neuropsychological assessments and neuroimaging observations (3 different occasions, 2 years apart), academic researchers (Nutley et al, 2014) demonstrates that practicing a musical instrument was associated with higher performance on tests of visual-spatial working memory, verbal working memory, processing speed, and reasoning ability, with exception to reading comprehension, all of that belonging to executive function abilities. Even more, this study finds also a greater gray matter density in some particular regions of the brain (related to music notation decoding) and a better mathematics performance on music training groups versus non-music groups. Time spent on music practice has a positive influence and predict the working memory development. The authors conclude that “these results indicate that music practice positively affects working memory development and support the importance of practice for the development of working memory during childhood and adolescence” (Nutley et al, 2014, p. 7).

Finally, not least important but not sufficient and deeply researched, one study suggests that any impact of music lessons on intelligence may be mediated by the improved of certain executive functions skills, of which selective attention and inhibition control seems to has the strongest positive influence (Degé et al., abstract, 2011). In reality, on the association between music lessons and intelligence, it seems scientifically plausible to consider the importance of early music instrumental experiences on shaping the development of executive functions, which are considered fundamental to improve intellectual, emotional, self-regulation and social capacities through the childhood, adolescence and young adult years of academic frequency (Center on the Developing Children, Harvard University, 2011).

Concluding, formal musical training since early ages and frequent practice is associated with enhanced intellectual development and increasingly development of some elements of executive functions. Executive functions are crucial to enable children, adolescents or younger adults to be more proficient and flexible on learning (intelligent development) through academic life and lifespan human development. However, further longitudinal studies seem to be necessary to determine the causality (or not) of the positive association between early music training and intellectual development and/or similar association between music training and executive functions development.

2.3.3.5. General attainment and creativity

2.3.3.5.1. *Music lessons and general attainment*

The researching central question related with this topic is about the impact of student’s participation in music education on academic attainment. A significant number of correlational studies, namely referring to the American educational system, show evidence that students engaged in music education (training) had higher achievement results in general or in many measures of academic performance than their peers with no-musical training (Hallam, 2010). This positive correlation is more strongly related with early music training and over long periods of music practice, even when intelligence variable was taken into account (Schellenberg, 2006). Motivation, quality of the music programme, type of musical activity and the opportunities provided to students for performance which contributed to enhance self-esteem and self-efficacy also matters on positive effect on school performance (Hallam, 2010).

However, causal explanations on correlational studies were difficult to establish given the fact that parental music support and their family socio-economic and cultural status have influences on children option to be engaged on music and subsequently practice and achievement for better academic results. Students that choose to study music may be already academically better than their peers who choose not to (Hallam, 2010, 2015).

Arts education, which includes music education, visual arts, dance, drama and multi-arts programmes, has been also object of various studies about their relation with academic achievement. During the American years of the "No Child Left Behind", there was a strong support to the student's learning experiences in "the arts" and plenty convictions about their positive contribution to a better academic achievement. Critical Evidence – How the Arts Benefit Student Achievement written by Sandra S. Ruppert (2006) is a clear example of advocacy that "the arts" should be integral part of the core curriculum in all American schools based on evidence research findings that identified six major types of benefits: reading and language skills, mathematics skills, thinking skills, social skills, motivation to learn and positive school environment. The educational principles traced on "No Child Left Behind" seem consensual and universal acceptable, but the big question is about how those principles would be supported on the field, opportune time and environment circumstances:

> The evidence is clear: study of the arts contributes to student achievement and success. Its multiple benefits are academic, basic and comprehensive. What is less clear is how to ensure that all students have the opportunity to learn about and experience the arts in the school. Despite convincing research and strong public support, the arts remain on the margins of education, often the last to be added and the first to be dropped in times of strained budgets and shifting priorities. (Critical Evidence, p. 17)

Meanwhile, and more recently, other researchers (Swaminathan and Schellenberg, 2015) exploring the associations between arts education, cognitive ability and academic achievement, corroborate a large academic literature linking positive effects of any forms of art involvement (dance, drama, music and visual arts) to academic achievement, such as when arts training students reported higher scores on the

Scholastic Aptitude Test (SAT) during a meta-analysis of 10 years data collected from the American College Board (1988-98).

However, training in different forms of arts may be associated with differentiated performance on specific academic subjects. For example, music training positive associations with mathematical skills seems more evident than the association between music training and language abilities, although these results appear not always consensual among researchers. Also significant is the duration of the arts training: in general, longer participation on arts training is accompanied with higher levels of academic achievement. And there is strong evidence that associations between training and academic achievement could be a consequence of individual differences on socio-economic status, which is known to predict academic achievement (Swaminathan and Schellenberg, 2015, p.366).

To clarify the claimed links between arts involvement and academic achievement, some researchers found out that involvement in after-school arts improve academic performance only if the involvement consists on learning and practice a musical instrument (Young et al., 2013). The after-school participation of children on non-musical arts, such as sports, does not show cognitive advantages and evidences of better school outcomes. So, according to the authors "arts involvement predicts academic achievement only when the child has a musical instrument" and this happens regardless of income level, parental status and other social-factors. These differentiated results may be explained by the rich nature of the neural tasks and great plasticity involved on music learning and practice, which does not be occurred on other arts training, as mentioned by Schellenberg (2006) who argued that music instrumental lessons may enhance IQ and academic performance.

However, pre-existing individual differences could also influence the correlation between music training and academic achievement, and by that reason a causal relationship is difficult to prove using correlational studies. Some longitudinal and experimental studies tries to find a causal relation between music training and academic achievement, such as that one, developed by Eugenia Costa-Giomi (2004) about the study of the effects of three years of piano instruction on children that had never participated in formal music instruction and were objected of several tests covering aspects such as self-esteem, cognitive abilities, musical abilities, motor proficiency and academic achievement. Pre-existing individual differences on children participants (e.g., sex, family income, parental employment, and family structure) were objected of critical control. According to their experimental study and discussion the author's conclusion indicates that there are specific benefits associated with extended participation in piano instruction, especially the development of self-esteem and school music marks, but fail to prove a causal relationship between formal music instruction and academic achievement in mathematics and language.

The processes and dynamics to teach/learning a musical instrument may have a significantly influence on the positive effects on school achievement. One of the most interesting findings on music instrumental learning is about the influence of interpersonal interaction amongst teachers, pupils and parents on the quality and learning output of the musical instruction. In particular, in the context of learning a musical instrument, pupils' perception of the important dimensions of control and responsiveness and interpersonal dynamics with their teachers and parents were associated with positive music learning outcomes (Creech and Hallam, 2011). Additionally, student's motivation is also crucial on achieving musical competence and success in school, as high motivation is closely related with self-perceptions of ability, self-efficacy and aspirations (Hallam, 2015).

So, it seems that interpersonal dynamic learning, student's high motivation, quality of the programme and music successful attainment on music instruction all of that matters on achieving positive effects in general school achievement. In this context, we could consider that interpersonal dynamics on learning and practice music may be a predictor for the achievement of positive outcomes in both musical and general learning.

2.3.3.5.2. ***El Sistema***

Also relevant, "El Sistema and Sistema" musical programme focuses on children in schools in deprived areas (UK), shows that with just one year of musical practice involvement was enough to those children to report better scores in mathematics, reading and writing when compared with their peers not involved. Similar results with El Sistema programmes were found in USA with children participation demonstrating significant and steady improvement in academic attainment. Some cases these groups of comparison do outperform in mathematics, reading and writing. There is some evidence that prolonged and cumulative engagement in the programme leads to more positive and consistent effects on academic achievement. (Hallam, 2015, p.71)

El Sistema, an abbreviation of La Fundación del Estado para el SistemaNacional de Las Orquestras Juveniles e Infantiles de Venezuela, is the result of a Venezuelan social music education programme established by José Antonio Abreu in 1970s. The conception of the El Sistema is somewhat inspired in Paulo Freire's idea of an educational praxis retrieved on the "Pedagogy of the Oppressed" (1973), which points out to reflection and action upon the world in order to transform it.

In recent years, the prominence of El Sistema has risen significantly on the international scene. El Sistema programs or similar ones have already been established in cities or countries such as Los Angeles, Boston, Scotland, Liverpool, Norwich and Portugal (Uy, 2012). The central idea is to provide instrumental music instruction to children, no matter what social, economic or cultural differences they may have, one to four hours everyday after-school lessons, and give to them the opportunity to play in orchestra, in a chamber group or in a choir, with frequently give performances to the public. Through frequent performances, students have many opportunities to demonstrate musical qualities and to share their aspirations with their peers, family and community. El Sistema is not just a musical programme, but rather has a pedagogic action about core values:

> El Sistema is … a set of inspiring ideals which inform an intensive youth music program that seeks to effect social change through the ambitious pursuit of musical excellence. El Sistema focuses primarily on children with the fewest resources and greatest need (Eric Booth, Fundamental Elements of Venezuela's El Sistema 2013, p.1).

Furthermore, as supported by multiple experiences and studies (Michael Uy, 2012 and others), researchers highlight that El Sistema by programming regular after-school serious artistic instruction to children, some of them coming from families living in adversely socioeconomic conditions, inculcated values of working together, concern, sharing responsibility and empathy toward others, promotes interactions between students participants, families and their communities, and contributes to improve student's cognitive development and learning environment, all of that favorable to a superior academic achievement and a greater social inclusion.

In conclusion, the evidence suggests a clear relationship between active music instruction of children, adolescents or young adults and general school attainment. The relationship may be mediated by the more or less positive impacts of music learning and training on literacy, numeracy, executive functions, and intellectual, emotional, psychological and social development of the Younger's music participants.

2.3.3.6. Music lessons and creativity

Development of creative skills may be another positive effect associated with musical engagement, but this matter has been subjected to less attention from research community.

Neuroscientists Antonio and Hanna Damasio highlight the emotional role of arts and humanities and their effects on fostering the imagination that is necessary for innovation and human healthy development: "Arts and humanities education can convey the moral structured that is required for a healthy society and is so challenged by current social developments"… "To forget arts and humanities in the new curricula is equivalent to sociocultural suicide." (Damasio, UNESCO Conference on Arts Education, 2006).

The development of creativity skills is likely to be particularly dependent on the type of musical engagement, with musical improvisation and composition leading the potentiality of creativity. Improvisation and composition are the basic forms of generating new ideas in music. Jazz is recognized to be the most eligible form to express music improvisation, although some kind of improvisation in performance of classical music could be possible while not common. But the latest one exercise precludes the personal musical ability to technical dominate the original composition, while refining some ideas or introducing rearrangements of existing music to create something different and aesthetic valuable. During Beethoven's era piano improvisation was not that rare as it is nowadays.

One study relative to musical creativity, using brain images techniques, found that during improvisation brain areas deactivated are the same during dreaming and meditation, while activated areas include those controlling language and sensorimotor skills (López-Gonzalez et al., 2012). The same study concludes that creativity neither be localized to a single area in the brain nor boxed into a single process phenomenon.

Emotion is usually assumed to guide much of the artistic creation (Damasio, 2006). Emotion and creativity are strongly connected components of learning proficiency, innovation and flexibility. An arts-rich school environment promotes creativity, higher-order thinking and problem-solving skills. Learning improved by arts training or learning through musical training has been objected of scientific research support (Gardiner, 2000): "Music and arts appear to be especially rich in their use of mental strategies, very similar to mental strategies called upon in quite different areas of application"(Gardiner, 2000, p. 1, 2).

Musical instruction, with various merits and benefits, may also be subjected to further research to include musical pedagogical teaching on class-room to enhance general student creativity in order to prepare young students for a better learning on different academic domains and probably more innovative and changeable social contexts trough long life.

2.3.3.7. Social, Emotional and Personal Development

Musical training provides a widespread of positive impacts (benefits) on children and younger development that extend beyond the intellectual and cognitive abilities. The social, emotional and personal benefits of music instrumental are differentiated, among other variables, by the individual practice of the instrument or by the practice in group – ensemble, choral group, chamber music, "bands" or orchestra. Playing in a musical group is a rich opportunity to children or young people to develop some kinds of socio-emotional skills, such as teamwork, trust, individual respect, emotional control, and also to foster self-esteem, sociability and social inclusion. Experience in music groups also fosters school and social integration between underprivileged children and promotes a sense of positive contribution to the society (Hallam, 2010, 2015).

In turn, the individual learning and practice of a musical instrument, such as the piano, has significant requirements and implications on cognitive, physical and personal development with specific outcomes on socio-emotional skills (e.g. perseverance, resilience, self-discipline, emotional control) and physical abilities (e.g. fine motor skills, dexterity of both hands, pedaling coordination, musical-kinesthetic dynamics). This will be more evident when the start of instrument learning happens on a sensitive or optimal period (middle childhood). Combination of theoretical instruction, individual instrumental learning and practice integrated in a music group is the most common situation on children's music education (even piano can be played in a chamber group, concert, vocal accompaniment or "lied" songs). Individual and collective music instrumental practice is ideal to foster multiple socio-emotional skills and physical abilities, shaping the personality of the younger student with implications on their learning abilities on academic and life-span.

2.3.3.7.1. ***The relevance of social and emotional skills***

For the OECD the central massage to face the educational challenges of the 21st century is to develop a "whole child" with "a balanced set of cognitive, social and emotional skills for achieving positive life outcomes" (OECD, 2015, p.13).

According to OECD (2015), social and emotional skills that guide children's lifetime success are those that raise individuals' capacity to achieve goals, work with others and manage emotions. "Achieving goals" include skills like responsibility, persistence or perseverance and self-efficacy. "Working with others" refers to skills such as extraversion or sociability and adaptability. "Managing emotions" is susceptible to include skills like reactivity or mood, self-confidence and self-esteem.

The contribute of music training to foster a balanced set of cognitive, social and emotional skills on children's development should not be overlooked by education stakeholders and, by contrary, should be understand as a positive answer to the question introduced by OECD "how to foster social and emotional skills?" (OECD, 2015, p.129)

As referred in the OECD report (p.132) "Among the most important drivers of lifetime outcomes include skills that increase children's capability to achieved goals (e.g. perseverance), work with others (e.g. sociability) and managed emotions (e.g. self-esteem)". To this purpose, music training can be a useful educational tool to acquire the three above mentioned individual capabilities, in order to enhance social and emotional skills.

2.3.3.7.2. ***Musical training foster social and emotional skills***

In reality, despite the links between musical training and literacy, numeracy or other intellectual abilities have been much more and deeply researched, there are a considerable number of studies or review of research that demonstrated also the positive impact of music on children's socio-emotional development, including self-esteem, confidence, motivation, sense of achievement, emotional intelligence, responsibility and other social skills (Susan Hallam in "The Power of Music: Its impact on the intellectual, social and personal development"; 2010 and 2015).

Educational music engagement can be related to positive attitudes towards school and better attendance, and some musical programmes like "El Sistema" or "Sistema-inspired" focus on students coming from the most vulnerable families verifying academic positive outcomes and also a better social inclusion among their communities. The orchestral program "El Sistema" inspired in Venezuelan creator José Antonio Abreu (1975) and it is based on the central idea that "social action through the music" is considered a good example of individual benefits of the musical activity among the participants (some of them poor and/or at-risk of social exclusion), creating a positive space for self-affirmation, working partnership, openness to new realities and values, rediscovering self-esteem and a positive sense of citizenship (Hallam, 2015; Uy, 2012; Booth, 2013).

Merits of the El Sistema inspired a program in Los Angeles on the development of musical skills of underprivileged children just after an intensive music training of 1 year were confirmed in a recently published research (Ilari et al, 2016). The results of the study are interesting on the perspective that potential development of musical skills should not be considered an exclusive of middle class children who usually have more access to learn music in school and conservatoires. The authors stress (p.11):

> Most importantly, our findings suggest that different musical skills develop in childhood based on the combination of children's individual interests, parental support, formal music training, and everyday musical experiences, with social markers like socioeconomic status playing less important roles.

Musical engagement in group in form of chamber music, choral group, bands or orchestral fosters some important social skills as pointed out by Susan Hallam (2015, p.84):

> Group music making clearly has the potential to promote social cohesion and support inclusion. Making music with others creates bonds which are not easily created in other ways. This process may also lead participating individuals to become more tolerant and accepting of others and their beliefs is social ethics.

Further social benefits of group music can be added (Hallam, 2015, p.88):

> Making music with others in small and large groups requires team work, particularly when music is to be performed. Team work relies on participating individuals supporting each other and developing trust and respect. Group making provides an ideal vehicle for developing prosocial, team working skills.

Other musical experience with students aged 9 years attending public schools in Montreal and coming from lower income families show evidence that piano instruction during three years had a positive effect on children's self-esteem (Costa-Giomi, 2004). This finding is even more relevant because (p.148): "The positive effect of piano instruction on self-esteem was evident regardless of children's sex, parental employment and family income and structure."

When discussing the effects of musical training on foster social skills it is impossible to ignore the associations between music and emotion and the role of the emotions on cognitive learning processes or social behavior. Explained in part 2.2.6 of this dissertation, music-evoked emotions may be critical to correlate with brain structures that facilitate abstraction, sociability and learning capabilities. Learning and playing music involves almost every cognitive function and positive emotions and pleasure and reward emotional states induced by music experience may smooth future learning and may have other transferable benefits, such as pro-social skills and a balanced human development.

Furthermore, some findings showed a positive association between music making and emotional intelligence, but the results are not consensual and had mix findings. "The evidence suggests that group music making can support the development of empathy and emotional intelligence although the evidence relating to the latter is less clear" (Susan Hallam, 2015, p.90).

2.3.3.7.3. *Music training influences on health, well-being and personal development*

The role of music in health has been object of an increasing research interest. Music seems to elicit emotions and change moods through its stimulation of the autonomic nervous system. Bodily responses related to emotions in music include changes of dopamine associated with reward in listening or processing music. In addition, music generates a wide range of physiological effects on the human body including changes in heart rate, respiration, blood pressure, skin conductivity, skin temperature, muscle attention, and biochemical responses (Hallam, 2015, p. 99).

Even more, music training can be considered a lifelong investment to protect the brain from ageing and hearing loss, as suggested by a recently study (Krauss and White-Schwoch, 2014, p.117):

> Music training has emerged as a potential tool to set up the brain for healthy ageing. Due to overlap between neural circuits dedicated to speech and music, and the stronger engagement of cognitive, sensorimotor, and reward circuits

during music making, music training is thought to be a stronger driver of neural plasticity.

Music training affects not just the cognitive and physical abilities of children. Music initiation and practice relates also with the personality of the young musician and it may be more probable that those who are more self-disciplined are more likely to preserve in learning a musical instrument (Hallam, 2015, p.74).

In summary, music learning and training involves strong motivation, self-discipline, concentration, emotional intelligence, perseverance and resilience to achieve developing expertise, all of that shaping the personality of the younger musician with implications on their cognitive, socio-emotional and individuality development.

3. METHODOLOGY

The qualitative research approach of this interdisciplinary study includes a strategy to delimit the scope of the research facing the large body of investigation of neuroscience applied to music and education. The qualitative research is focused on the findings of neuroscience applied to music training, rather than on music listen or music backward, and their transfer effects on non-musical domains. Concomitantly, some criterions were adopted, namely the scientific relevance or/and the most up-date publication findings, when selected the academic literature that may be given some evidence or possible answers to the main research question.

In general, selective literature review observed the following three dominant criterions: (i) relevant and up-dated for the thematic of the dissertation; (ii) published on academic journal or through scientific organizations/editors, or by recognized researchers; and (iii) have significance for learning/educational paradigms.

Basic and generalist scientific literature was selected to proportionate an overall introduction to basic concepts, methodologies and scientific findings or to facilitate the contextualization and theoretical comprehension of the subjects analysed and discussed on the dissertation. These are the cases of the: “The Human Brain Book” (Rita Carter, 2009), “Cérebro, Saúde e Sociedade“ (Armando Sena, 2016), “Essential Neuroscience” (Allan Siegel and Hreday N. Sapru, 2011), “Understanding the Brain: The Birth of a Learning Science” (OECD, 2007), “Understanding of literacy in Education for All Global Monitoring Report 2006” (UNESCO, 2006), “Skills for Social Progress: The Power of Social and Emotional Skills” (OECD, 2015), “Human Neuroplasticity and Education” (Vatican City, 2011), “The Dana Sourcebook of Brain Science” (Dana Foundation, 2003) and “This Is Your Brain on Music” (Daniel J. Levitin, 2006).

The dissertation adopts also an integrative research review methodology to analyse and do a critical overview of the academic literature on the fields of neuroscience, music and education and on their interdisciplinary thematics for the specific purpose to collect scientific evidence or relevant knowledge that gives answers or essential reflections to the main research problem and research question.

Also, the author uses the autobiography approach (a research process based on qualitative data analysis) that regards life stories – based on narratives (1st person) and memory field notes (3rd person observation) - as a method to gather data to bring forth knowledge and merge with the thematic of this dissertation. In that sense, the autobiography is organized in a sequential way from the marking key events that stays not only in the past but also covers the present and future developments.

Finally in this dissertation there is a clear option to use a qualitative approach, rather than a quantitative approach, by the essential reason that the thematic proposed and the main research question is almost impossible to be answered by applying a questionnaire, interview or other quantitative instruments. In reality, the thematic proposal: "Music training influences on brain development and as tool for learning improved", and the main research question "What is the impact of music training in cognitive and personal development?" requires the use of an integrative literature research review on the disciplinary fields of neuroscience, music and education, and their interconnections subjects, researching thematics and findings. It should be noted that, for instance, the brain's differences between musicians and nonmusicians have been objected of scientific findings with the resource of neuroimaging techniques. These findings are essential to explain the impact of music training on changing the brain and their possible positives effects on cognition and personal development. The no option for a "study-case" approach is related with the fact this methodological approach requires time and a lot of resources focused on a more restrict research area.

4. DISCUSSION

The overall review literature reveals that music training has strong influences on the brain throughout the notable neuroplasticity induced by music experience-dependent, which is related with the acquisition and practice of musical abilities.

Neuroscientists with the resource of modern neuroimaging techniques concluded that there are structural (regional) brain differences between musicians and nonmusicians. There are brain differences related with the brain regions involving with the practice of music, such as motor cortex, sensory cortex, auditory cortex, visual cortex, corpus callosum, hippocampus, among others.

In particular, the corpus callosum assumes a vital function on the music training processing, connecting the two hemispheres and facilitating the interaction between the coordination of motor bimanual hand and the exercise of other musical functions. There is evidence that the corpus callosum is subjected to a greater neural activity induced by music, and it seems that anatomical differences facing "nonmusicians" are larger in the case of the "musicians" that start training before the age of seven, which is in line with the period of maturation of the corpus callosum (4-11 years).

But all of this exceptional musician cerebral activity suggests the reasonability of the main research question in these terms: what is the impact of music training in cognitive and personal development?

In reality, music learning and training requires a complex and enriching neural activities, strictly associated with development of some cognitive functions or tasks, like sight-reading, extensive memory, pitch and tonal perception, auditory fitness on discriminating musical sounds, bimanual coordination and dexterity (eventually complemented with pedal dexterity), motor-sensory coordination, executive functions, and emotional responses to music.

The impact of music training in cognitive development depends on the degree of musical expertise, provided by extensive, intensive and qualitative music training. For instance, according to my experience as pianist, there is a positive association between the degrees of music/extensive practice and the capacity of memorize the music (playing without score). Expertise in piano also requires an elevated degree of dexterity on both hands and coordination with pedal movements, sometimes forgotten as an important piano ability.

Moreover, the brain changes to instrumental practice in response to the core principles of neuroplasticity (Kleim& Jones, 2008) and according a set of moderating variables of music training-induced neuroplasticity (Merrett at al., 2013), such as age of commencing training, genetic predisposition, personality, family background, gender, “absolute pitch” ability, type of instrument and intensity and accumulated training practice.

Music training beginning in middle childhood (5-6 years old), sensitive period of learning, is assumed by neuroscientists that may have a decisive influence on promoting qualitative musical abilities and to enhance the brain learning capabilities across the life span. Educational music training should take in serious consideration this “window of opportunity” of beginning music training as happens with acquisition and improvement of language abilities.

In my view, other influent variables in children music training, not referred by the cited authors, include the student’s parental support, motivation, perseverance, emotional control and experiences of pleasurable and reward on learning and playing a musical instrument. Additionally, an adequate curriculum programme and quality of teaching also matters on children music training and other benefits.

In summary, expressing the complexity and enriched cognitive and personal experience of the musical training on changing the brain Sara Wilson writes: “… music making draw on a range of highly developed and well integrated sensory, perceptual and motor skills, as well emotions and higher order cognitive and attentional functions” (Wilson, 2013, p.141).

It is also important not forget that emotions assumes a decisive role on music processing and also influences personal development.

In fact, music training is at the same time a cultural, developmental and biological experience-dependent learning of a set of musical abilities and a specific source of cognition and it is impossible, in my view, to dissociate musical activity (listening, playing, singing, composing or teaching) from emotion.

According to my experience as pianist, music performance is an integrated aesthetical, technical and emotional human artistic expression. Music instrumental learning should involve the emotions as an essential component of the communication professor/student and also as a central component on understanding the aesthetic and personal ideas of the composer/piece of music.

Even more, the potential of music to evoke emotions makes music learning and training a valuable tool to provide an affective, motivate and creative framework in education to general learning and personal development. Affective engagement with music may give to children more confidence to learning.

The benefits of music training for the children's cognitive and personal development can be extended to nonmusical domains, as a vast academic literature demonstrates or suggests.

Dynamics and structural neuroplastic changes on brain resulting from the practice of a musical instrument suggested other brain potential effects on nonmusical cognitive, social and emotional abilities and personal development. All of this may be occurring by the near or far transfer of musical abilities to nonmusical abilities, or simply by the fact that music training induced neuroplastic "primes" the brain for future learning.

Transfer is a central concept in education because most formal education aspires to transfer what is learning in the school-environment to other environment contexts, such as in the job, at home or in the society. Positive transfer occurs when learning in one context improves learning in other context. Consequently, the final purpose of education is not achieved unless transfer occurs.

Transfer includes near transfer (to closely related contexts and/or tasks) and far transfer (to rather different contexts and/or tasks). Transfer is more probable to occur at near transfer level and/or when tasks share identical or similar elements or cognitive processes (Perkins and Salomon, 1992). Some musical skills are more likely to transfer than others, for instance that one that involves reading notation (musical ability) and reading text (language ability), or when using the same mathematics relationships, proportions and fractions to processing notes, rhythmic and other musical sounds (notation) and to learn and exercise mathematics (course).

Overall, the versatility and complexity of the brain's cognitive and emotional activity while practicing musical skills may lead to transfer effects in nonmusical skills and other human benefits, such as language and literacy, mathematics and spatial abilities, intellectual development and executive functions, general attainment and creativity and social, emotional and personal development.

Language and music are among the most complex intellectual features of the human brain. The relation between language and musician has been a long time topic of cognitive and biological research. Learning a language is susceptible to a sensitive period and, for instance, initial exposure to grammar and phonological processing is mostly effectively learned before the end of the children period.

Neuroscience findings show that children with music training improves their auditory skills and have a better vocabulary and a great reading ability compared with children peers that did not received music training (Kraus & Chandrasekaran, 2010). This finding has serious implications for education, in the sense that clearly favours the introduction of formal music training in the children educational curriculum. The earlier the exposure to musical learning and training the greater is the impact on developing neural auditory skills which improves language acquisition and development of linguistic abilities.

Additionally, positive associations between music training and literacy achievement are found, considering that children with music practice are more self-disciplined, able to selective attention and focus for long periods of time which favours reading with comprehension (literacy ability). In particular, the positive influence of music instruction on literacy development has been found, among other investigations, on a longitudinal study involving children from low-socioeconomic status in Los Angeles and on other musical experiences, such as the program “El Sistema”. Both suggest an important role of music education on promoting literacy in children from social disadvantageous groups.

In summary, the selected literature review demonstrates that children with early and consistent engagement with musical training reveal significant improvements in neural auditory skills and develops specific musical abilities, which are subjected to near or far transfer to enhance linguistic abilities and reading with comprehension (literacy ability). Music and dance had been, since early childhood, a notable influence in my life, improving fine discrimination of the sounds and a more sophisticated auditory cortex leading to a singular positive impact on my aural difficulties and other benefits on my cognitive, emotional and personal development. It is quite impossible to disassociate my well-succeed academic path and high qualification on piano performance without a reference to my important experience on music training and dance since early childhood.

Concerning to mathematics and spatial reasoning, it seems that children exposure to music promotes the development of that skills, but the correlation is much more evident on active music participation, rather than on listening music. Abstraction associated with music seems advantageous to some mathematics reasoning. The ability to processing mathematics is just one partial distinct intelligences (Gardner & Hatche, 1989), and exceptional ability or deficit in mathematics does not necessary imply talents or deficits in other cognitive domains. The ability in a certain subdomain of mathematics is not necessarily indicative of a global mathematic ability. In general, processing mathematics involves genetics predispositions (nature) combined with experience and environments factors (nurture), such as a good programme, quality of teaching and an adequate age of beginning to study math.

Passive exposure to music, like listening a piano sonata of Mozart for some few minutes, just result in a small enhancement of the spatial performance and with short term duration, and general intelligence is not affected ("Mozart effect" or "Mozart makes you smarter" is a myth). Probably that limited "effect" can be explained by temporary listener's mood and arousal generated by music that favours the test's performance by contrast with the other control groups not subjected to music stimuli. Music listening is not the same as music instruction and the effects of the later on mathematics or spatial abilities are more salient and for long–term duration, especially for children who begin lessons at an early age when the brain is more plastic.

In my experience, reading musical notes is related with counting lines and spaces to play the right notes. Also reading rhythm is always kept up with counting steady beats and implies how to learn the technical elements in the score. We can say that learning music and mathematics has some similarities. By integrating the music instruction and mathematical curricular on early childhood school phases it is expectable to have a beneficial effect on children mathematics achievement.

Mathematical reasoning involved in musical compositions is reflected in notation by different forms – time, rhythm, pitch, intervals and melody. Music itself is indeed very mathematical and mathematics is inherent to many basic ideas in musical sounds. Mathematics helps us to describe the conception and structural configuration of the composition. Composers or professional musicians (interpreters), or amateurs' musicians in a less scale are more familiarly with mathematics abstraction and also with auditory and visual working memory through their professional activity, which has associated effects on the enhancement neural activity related with processing of mathematical abilities.

In summary, the neuroscientific research findings, supported on neuroimaging observations, suggested that the correlation between formal musical training and math proficiency might be associated with improved working memory performance and an increased mathematical abstract representation. It seems also that there are somewhat common neural processing of music and math, and subsequent possible cognitive transfer, such as processing reading musical notes and processing some mathematical relational concepts, like proportions and fractions.

Early exposure to music training may have also a positive impact on enhancing children intellectual development. Spatial, sensorial-motor, sight-reading, fine tuning, working memory and music perception tasks related with music instrumental practice induces neuroplasticity and prepares the children's brain to positive transfer to nonmusical abilities, such as in the area of the intelligence performance. However, the association between music lessons and intelligence has been recognized as significantly complex and the influence of the individual roles of nature and nurture factors seems very variable.

The hypothetical relation of causality between music lessons and improved intelligence is difficult to confirm and may subsist in doubt because the difference in intelligence between musical trained and untrained children may come, for example, from the fact that children that take lessons are already more intelligent and coming from families with a relatively higher educational and economic-social status. Music training can also be associated with some improvement of the skills related with emotional intelligence, because learning and performing music requires perceiving, understanding, using with rationality and managing emotions during performances or in other social contexts.

In my personal view, as a pianist and a piano educator, the ability to decode the emotional content of a particular musical structure (tempo, mode, harmonic progression, rhythm, tonality, touch…) together with artistic sensibility to interpret a wide range of emotions based on the notation structure is essential and entirely subjective in each single performance. This view suggests that emotional intelligence should be present on children learning and practice music as well as being a critical role in education. Cognition and emotion must be seen as two interrelated aspects of leaning and emotional intelligence is essential on promoting lifespan learning.

In summary, it seems that early music training, rather than music listening, is associated with positive and long-duration impact on intellectual development (Schellenberg and others). However, the complexity of the relationship between music education and intelligence requires special care on the interpretation, namely due to the individual variability of the combination of nature and nurture factors and also to the existence of multiples intelligences and subdomains of intellectual development. It should be pointed out that the broad conclusion of a relation of causality between music training and general intelligence is difficult to prove or to verify and in some cases that causality may be refer to an intellectual specific subdomain, probably more related with some type of musical reasoning.

As a complex and multiple cognitive and emotional activity, music processing requires the select use of some executive functions, such as auditory and spatial working memory, selective and sustains attention, creativity, problem solving and decision making. Some elements of executive functioning are clearly enhanced by musical training, such as working memory which is vital to music expertise or music performance. Findings confirming that musicians do better on working memory tasks than nonmusicians, giving their ability to exercise sustained cognitive control on music processing. In resume, formal music training since early ages and frequent practice is associated with enhanced development of some elements of executive function and may contribute to favour some aspects of the children and younger intellectual development.

In relation to general attainment, a significant number of studies show evidence that student's engagement in music lessons (training) had higher achievement results on academic performance than their peers with nonmusical training. This positive correlation is more evident with earlier music training and with extensive periods of music practice. Motivation, quality of the music programme, type of musical activity and the opportunities provided to students for performance and enhancement of their self-esteem also matters to school performance (Hallam, 2010 and 2015). But in these correlational studies is difficult to confirm a causal relationship because students that choose to study music may be already academically better performers than their peers, as well as individual differences on socio-economic status has been known to predict academic achievement.

Altogether, transfer effects from music training to general school attainment were subjected to be influenced by a set of variables that compose the individual nature and nurture factors of each music student. The positive correlation finding in some studies may be mediated by the more or less positive impacts of early music training on literacy, numeracy, executive functions and on intellectual, emotional, psychological and social development, which impacts on general academic achievement. Further longitudinal investigation needs to be developed on study's causal relationship between music training and academic achievement, which is not yet confirmed.

Music practice as well as arts involvement may foster the imagination and positive emotions on academic life and for the lifespan, with implications in human healthy development and a more creative society. Emotion and creativity are strongly connected components of learning proficiency, innovative and adaptable to new environments. Emotion is usually assumed to guide much art creation and it is on the core of learning and creative processes. According my professional background, music instrumental training should be subjected to further research on pedagogical teaching on classroom to enhance general student creativity in order to prepare young students for a better learning on different domains and changeable social contexts through lifespan.

Finally, music training provides a widespread of positive impacts (benefits) on children and youngers' growth that extend beyond the intellectual and cognitive abilities. The social, emotional and personal benefits of music training are differentiated, among other variables, by the individual practice of the instrument and/or by the practice in group – ensemble, choral group, chamber music, "bands" or orchestra. Playing in a group is an opportunity to children and young people to develop socio-emotional skills, such as teamwork, trust, individual respect, emotional control, and also to foster self-esteem and sociability. Experience in music groups with opportunities of public performance, also fosters school attainment, values of working together and sharing responsibility and social integration between children at-risk of social exclusion, like the well-known orchestral group "El Sistema", somewhat inspired in Paulo Freire's pedagogic idea of social action towards a better world.

In fact, group music practice provides an ideal vehicle for developing prosocial skills, with more relevance among underprivileged children who usually have more difficult access to learn music outside curricular programs when compared to middle class children. This has clear implications on supporting the principle of no child left behind from educational music training.

It is impossible also to ignore the associations between music and emotion and the role of emotions on cognitive learning processes and social behavior. Learning and playing music involves almost every cognitive function and generates positive emotions, pleasure and reward emotional states that may have transferable benefits on learning improvement, pro-social skills, emotional intelligence and personal development. Music training can also be considered a lifelong investment on health and human well-being, through recurrent practice of music to protect the brain from ageing issues and hearing loss, or even using music for therapy uses.

The global balance of the impact of music training in cognitive and personal development is extremely positive. Musical abilities require the use of panoply of demanding cognitive functions or tasks that correlates with structural and functional neuroplastic changes. Music training transfer of learning to nonmusical cognitive abilities depends on a considerable number of variables, of which the age of beginning to learn and play a musical instrument seems to be one of the most influents. Nevertheless, evidences suggest positive associations between instrumental practice and linguistic, mathematical, intellectual, executive functions, creativity and general attainment abilities. Overall, music training improves cognitive development or general learning. The nexus between music training and education is based on neuroplasticity. Music training induced neuroplasticity improves human brain learning capabilities.

In general, children's music instrumental learning and practice involves motivation, self-discipline, concentration, emotional control, pleasurable and reward, perseverance and resilience to achieved the best results on developing musical expertise, all of that shaping the personality of the younger musician with positive transfer effects on their cognitive, socio-emotional and personal development. Even more, music training can be a useful educational tool to increased children's capacity to achieved goals, work with others and managed emotions (OECD, 2015); all together representing precious skills for achieving positive life outcomes.

The emergency of a new research question is a consequent result of the recognized children formal music training benefits on their cognitive and personal development:

Why music training should be introduced on childhood education?

The balance of the effects of music training on child's brain - cognitive, emotional, social and personal development - suggests the advocacy of the early formal music instruction (instrumental) for every child.

Music-training induced neuroplasticity not only changes the brain – structural and functional – but also primes the brain for futures changes, with possible implications on the educational role of the music education.

The notable neuroplasticity induced by music practice is a way to establish a bridge between music and education, because neuroplasticity is essential to a more fluid learning on academic life and through lifespan.

The introduction of formal music training for every child could be seen as a powerful educational tool to improve a more efficient learning and to expand the capacity of the brain to adapt to the world changing environments and experiences.

Neuroscience findings demonstrate that plasticity is essential for learning and depends on the period of learning. The infancy period of life (3 years up to 10 years) is susceptible to be considered a “sensitive period” or “window opportunity” for learning with more flexibility and proficiency. During the childhood period there is an exceptional period of synaptic growth and myelination that favours the brain transmission of information and dynamics of learning.

The age of commencement of music training is considered by neuroscientists as one of the most influent variables of music-induced neuroplasticity and their long-term benefits. Neuroscientific findings suggest the start of instrumental learning and practice before the age of seven, because they found some relative superior music skills among musicians that began before that age.

The school programme for children music training should be well-designed and should cover a reasonable duration and intensity of practice to assure the long-term positive effects of the early music-induced neuroplasticity. Perhaps, a period of around 5 years of education between 5 to 10 years old would be suitable for initiation and practice a musical instrument. A pre-musical education, coincident with the pre-primary school, could be introduced at ages 3-4 years old. However, what would be the ideal duration, intensity and specificity of the children music training to shape the brain for a neuroplastic long-term benefit is a great question, subjected for further research.

Beginning to sight-reading (read notation) could happen around 5 years old, to anticipate the initiation to read a text or to learn the first mathematics concepts, like proportions and fractions. At this age, aural training would help children to stimulate auditory discrimination of sounds which facilitates reading ability.

As children begin to engage on music training, their proficiency on musical abilities depends on the intensity and quality of the training, including individual lessons, and also on how the student learns and how they reflect about what they learned. This may exercise some influence on musical abilities transfer to nonmusical abilities, including on their extension and effectiveness.

Each participant on music training has its singular experience of learning and practice music, and by that reason, transference of their musical abilities to others activities are susceptible, among other factors, to individual differences. This will be valid for the “professional” musicians or “amateur” musicians, while in the last case the core principles of neuroplasticity should be taken in consideration, such as use it or lose it, repetition matters and intensity matters.

Children personal preference or aptitude for music, as well as motivation, perseverance and feel of pleasure and reward also matters on their continuous engagement with music. Music teaching strategies should always be adjusted to the singularity of each student, their musical features, emotional involving and aspirations. One educational strategy consists of looking for continuous motivation, sense of pleasure and reward on music practice which seems essential to assure the best results on the instrumental progression to expertise.

The music training programs should not be designed to prepare students to be professional musicians, but in any case quality, discipline and technical accuracy must be always present. The benefits and value of music education is not confined to the future "professional" musicians, but also to everyone with other professional lives.

Taking in consideration what is known about the positive effects of music training, it seems imperative to look towards to no child left behind regarding the access of musical instrumental training and their multiple benefits on cognitive development, emotional and social skills.

The principle of no child left behind in music education implies a strong responsibility for educators and politicians to assure enough public resources to implement this "great" principle in practice.

Music training could also play an important role on promoting emotional and social skills, especially among children coming from socio-economic and cultural disadvantage groups. By participating on musical groups, such as orchestra, ensemble, chamber music or vocal group, children at social-risk of exclusion, developed a range of socio-emotional skills, like working with others, empathy, perseverance responsibility, emotional control, self-esteem and increased sociability.

Opportunities to appear in public in form of musical group or individual performance are important for music instrumental students to achieve musical goals, get self-confidence and reward compensation, and also become more integrated in the school and their communities.

The historical and well-known musical-programme 'El Sistema" centred on the participation of children from lower socio-economic status constitutes an interesting case of how music (orchestral or other musical group) can transform, through a collective social action, the children's lives and their perspectives for a better future (Paulo Freire's ideas revisited).

Music lessons could also help children to developed values and behaviors that would contribute for their personal development and human well-being, such as discipline, perseverance, working together (on musical groups) and achieving results.

Even more, music training evokes a broad range of emotions and feelings, fosters superior working memory and strengths creativity, and all together contributes for a more proficient learning and news ways of thinking. Emotion is one essential component of learning and music is a driver of emotions.

In resume, children's educational music training can be a useful educational tool to increase children's capacity to learn with efficiency, achieved goals, work with others and managed emotions. The first human development benefit is related to intellectual and cognitive development and the other three benefits with socio-emotional skills as described by OECD (2015). All cited human development benefits could be better achieved through music education accessible for all children.

Despite the evidence of the referred benefits, supported by neuroscience and other science findings, the advocacy of music education for every child should not be exclusively confined to the argument that music training improves cognitive development and successful academic results.

Music has its own universal intrinsic artistic and social value. "Throughout human history and across all cultures, people have produced and enjoyed music." "Music appears to transcend time, place, and culture." (Peretz, 2006, p.2)

Recognizing the value of music for every child, the Education & Training Committee of Parliament of Victoria considers:

> Music has an integral role in children's lives. Research has found that Australian children highly value their participation in the Arts.
>
> Music is an essential element of a child's education because of its intrinsic value and role in developing the whole child.

(The value and benefits of music education, Parliament of Victoria, 2013, p. xxi)

The children's music education and its aesthetic values and benefits call for a holistic education vision, which privileges a more balanced human development between the intellectual and cognitive development and the emotional, artistic, social and personal development aspects in the "whole child" growth.

4.1. CONCLUSIONS

Music training involves a complex and enriched cognitive, emotional and personal experience on learning and improving musical abilities.

The brain changes to instrumental practice in function of the core principles of neuroplasticity and according a set of influent variables of music training-induced neuroplasticity, among which the age of commencing training assumes to be one of the most influent on the development of musical abilities and transfer of learning to nonmusical abilities.

Among other direct benefits, the potential of music to evoke emotions and being associated with pleasure and reward systems makes music learning and practice a valuable tool to provide an affective, motivated and creativity framework in education to general learning and personal development of all children.

The benefits of music training for children's cognitive and personal development can be extended to nonmusical domains, as a vast academic literature demonstrates or suggests, such as on language and literacy, mathematics and spatial abilities, intellectual development and executive functions, general attainment and creativity and social, emotional and personal development.

The extension of the positive effects of music training on other nonmusical domains may happen by the near or far transfer theories of learning, or simply by the fact that music training induced neuroplasticity "primes" the brain for future learning. The nexus of music education and education is assumed by neuroplasticity which is essential on learning human processes.

The global balance of the impact of early music training in cognitive and personal development is extremely positive. In general, children's music instrumental learning and practice involves self-discipline, concentration, emotional control, extensive memory, required sensorimotor coordination, auditory fitness, pleasurable and reward, perseverance and resilience to achieved the best results on developing musical expertise, all of that shaping the personality of the younger musician with positive transfer effects on their cognitive, socio-emotional and personal development.

The evidence of the effects of music training on child's brain – cognitive, emotional, social and personal development – suggests the advocacy of the early formal music instruction for every child.

Music training can be a useful educational tool to increase children's capacity to achieve goals, work with others and managed emotions, all together representing precious skills for achieving positive academic and lifespan outcomes, as proposed by OECD (2015).

For all of above reasons, the introduction of formal music training for every child could be seen as a powerful educational tool to improve a more efficient learning and increase the potentiality of the mind to adapt to word changing environments and experiences.

Neuroscience findings demonstrated that music training has a "sensitive period" for learning with more flexibility and proficiency and that period coincide with the infancy period (3 years up to 10 years); and subsequently an ideal period to beginning the formal education can be situated on the middle of childhood, 5-6 years age, with a pre-musical initiation at 3-4 years age.

Among other benefits, children music training during the "sensitive period" improves auditory skills which are the primary importance on a successful language acquisition and on enhancement of the auditory abilities (not only music domain) through lifespan.

4.2. FINAL NOTES

Taking in consideration what is known about the positive effects of music training, it seems imperative to afford that no child left behind from the access of musical instrumental training and their multiple benefits on cognitive development, emotional and social skills. This principle is strongly reinforced by the fact that practice music in groups also plays an important role on promoting emotional and social skills among children providing from socio-economic and cultural disadvantaged groups.

Finally, music has its own universal intrinsic artistic and social value. The apology of music education for every child should not be only confined to the argument that music training improves cognitive development and learning academic results. The children's music education and their aesthetic values and benefits call for a holistic education vision, with a more balanced between intellectual and cognitive development and emotional, artistic, social and personal aspects of the "whole child" development.

4.3. RECOMMENDATIONS

The dissertation adopts a qualitative research methodology that combines an interdisciplinary, integrative and critical literature overview on the scientific areas of neuroscience, music and education with the autobiography approach. The qualitative research is center on the main purpose of the thesis: to underline the relevance of the scientific advances on the neuroscience applied to music and their subsequent findings regarding the merits of music training to improve brain's plasticity and transfer of multiple benefits to nonmusical domains on children educational and personnel development.

By the multiple and researching evidence for human benefits, music training might be recognized as an additionally educational tool to proportionate a children's better neural network capable of enhancing the learning and adaptability to external environment through the life span. It seems that findings of empiric investigation matches with the findings discussed on literature overview related with neuroscience applied to music and education.

As understandable by the autobiography description, the dissertation is in great part founded on the singular experience of the author as pianist, music educator and a master student on education. This singular experience of the author also explains the affective and scientific motivation by the nature of the thematic proposed and the primary source of their reflections, opinions or expression of their own artistic sensibility on the researching chapter dedicated to discussion.

The scope of the study is concentrated on music training, that's about learning and practices a musical instrument in the cultural context of classical music instruction and other delimitation of the study refers to the functional uses of music on therapy and clinical rehabilitation, which are not considered in this dissertation despite their relevant and confirmed social and medical benefits.

The dissertation contributes to the dissemination of the neuroscience findings on music training and its implications for education and lifelong learning. It may be relevant to education in the sense that provides an integrative overview of the virtuosi connection between music, neuroscience and education and their benefits to children educational and long-life human development.

Further research should bring more bridges between music, neuroscience and education to reinforce the thematic of educational relevance to include musical education in the school curriculum. Particularly, the future research should focus how to implement music education in the school curriculum in order to maximize the benefits for children on cognitive, emotional, aesthetical, social and personal development aspects.

In my opinion, the school programme should be well-designated in terms of the ideal commencement age, duration, intensity and specificity of the children music training to contribute for a better learning on other cognitive areas and assure the long-term positive effects of the early music-induced neuroplasticity.

Although the programme's goal is not to prepare the students to become professional musicians, it should aim for qualitative teaching, discipline and technical rigor. The benefits and value of music education is not confined to the limited future "professional" musicians, but rather to everyone with other professional lives.

18 October 2016

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